

**CORRECTION OF MORPHOFUNCTIONAL ALTERATIONS IN SALIVARY  
GLANDS INDUCED BY CONSUMPTION OF HARD ALKALINE  
GROUNDWATER USING CITRIC ACID SUPPLEMENTATION**

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**Abstract:** The chronic consumption of hard, alkaline groundwater has been associated with morphofunctional changes in salivary glands, potentially impairing oral health and glandular secretory activity. This study investigates the corrective effect of citric acid supplementation on the structure and function of salivary glands in individuals consuming such water sources. Histological examination, salivary pH, and flow rate analysis were conducted in experimental models to assess glandular morphology and function. Results demonstrated that citric acid mitigates structural alterations and restores near-normal secretory function, suggesting its potential as a simple, accessible corrective measure for populations reliant on mineral-rich groundwater.

**Keywords:** Salivary glands, groundwater, hardness, alkalinity, citric acid, morphofunctional changes, oral health

### Introduction

In the current era, the conservation of drinking water and the protection of potable water sources have become pressing global challenges. One proposed solution involves the efficient utilization of groundwater resources. However, due to the differences in the chemical composition between groundwater and conventional drinking water supplied through municipal systems, the regular consumption of groundwater can lead to several physiological alterations in the organism. Since it initially contacts the oral cavity, the digestive system is considered to be directly affected.

This study investigates the morphofunctional changes occurring in the salivary glands and saliva of white laboratory rats subjected to the consumption of groundwater. A variety of analytical methods were employed to assess these alterations. Furthermore, the study explores the use of citric acid as a corrective agent to mitigate the adverse effects induced by groundwater intake.

In many arid and semi-arid regions, populations rely on hard, alkaline groundwater for daily consumption. Such water often contains elevated concentrations of calcium, magnesium, and bicarbonate ions, which can influence the body's physiological systems. Prolonged intake may lead to structural and functional changes in the salivary glands, potentially

resulting in xerostomia, altered saliva composition, and subsequent oral health issues. Recent research suggests that mild dietary acidulants, such as citric acid, may help restore salivary gland function by balancing pH levels and stimulating salivation. This study aims to evaluate the potential corrective role of citric acid on morphofunctional alterations in salivary glands induced by high-mineral groundwater consumption.

## **Materials and Methods**

### Experimental Design:

A total of 40 adult Wistar rats were divided into four groups (n=10):

Group I (Control): Received distilled water

Group II: Received hard, alkaline groundwater

Group III: Groundwater + citric acid supplementation (0.5% in drinking water)

Group IV: Groundwater + post-treatment with citric acid after 30 days

### Water Analysis:

Groundwater was analyzed for pH, total hardness (as CaCO<sub>3</sub>), and mineral content using standard laboratory methods.

### Histological Evaluation:

Parotid and submandibular glands were excised and processed for hematoxylin and eosin (H&E) staining. Morphological parameters including acinar integrity, ductal dilation, and lymphocytic infiltration were assessed.

### Saliva Collection and Analysis:

Saliva samples were stimulated using pilocarpine and analyzed for flow rate, pH, and bicarbonate content.

## **Results**

### 1. Stimulates Saliva Production

Citric acid activates taste receptors, especially sour ones, which triggers more saliva production.

Increased saliva helps naturally cleanse the mouth, flushing out food particles and bacteria.

### 2. Helps Maintain Oral pH Balance

More saliva means a more stable pH level in the mouth, reducing acidity.

This helps protect tooth enamel from erosion and limits the growth of harmful bacteria.

### 3. May Have Mild Antibacterial Effects

While not a replacement for oral hygiene, citric acid has mild antibacterial properties that can reduce some bacterial load temporarily.

#### Water Composition:

The groundwater had a pH of 8.2 and total hardness exceeding 350 mg/L as CaCO<sub>3</sub>.

#### Salivary Flow and pH:

Group II exhibited significantly reduced salivary flow ( $p < 0.05$ ) and elevated pH compared to controls. Groups III and IV showed partial to full restoration of flow rates and pH toward physiological levels.

#### Histological Findings:

Group II glands showed acinar degeneration, ductal expansion, and mild inflammation. These changes were significantly reduced in Group III and nearly absent in Group IV, indicating a restorative effect of citric acid.

### Discussion

The data demonstrate that prolonged ingestion of hard, alkaline groundwater induces structural and functional disturbances in salivary glands. These effects are likely linked to altered ionic balance and systemic pH buffering mechanisms. Citric acid, as a natural chelating and acidifying agent, appears to counteract these effects by stimulating salivation, improving ionic solubility, and normalizing pH. These findings are consistent with prior reports on the protective effects of dietary acids on oral and digestive secretory systems.

### Conclusion

Citric acid supplementation effectively mitigates the adverse morphofunctional effects of consuming hard, alkaline groundwater on salivary glands. This approach may offer a simple, low-cost intervention to support oral health in affected populations, particularly in regions where water softening infrastructure is lacking.

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