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Spectrophotometric Analysis of Fluoride Concentration in Toothpaste

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قياس تركيز الفلوريد في معاجين الاسنان باستخدام الطرق الطيفية

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Abstract:
This study aims to evaluate the fluoride levels in toothpaste products currently sold in the Libyan market. 30 different brands of toothpaste products (9 for children and 21 for adults) were analyzed to evaluate their fluoride concentrations. A spectrophotometric method; was employed to assess the fluoride concentration. Results showed that nine tested children's toothpaste samples contained a fluoride level below 500 ppm, which suits kids. In contrast, 18 adult toothpaste samples had a total fluoride concentration of 500 and 1500 ppm. Three adult toothpaste samples exceeded the recommended fluoride concentration more than 2000 ppm. The analysis revealed that 85.7% of the samples contained fluoride within permissible limits, while 14.3% had fluoride levels higher than the allowable limits. It can be concluded that the fluoride content in children's toothpaste appears to be in line with the recommended optimal amounts. However, there was a widespread disparity in fluoride concentrations for other samples.

Keywords: Spectrophotometer, SPADNS method, Dentifrices, Fluoride, Toothpaste.

الملخص
تهدف هذه الدراسة إلى تقييم مستويات الفلوريد في منتجات معاجين الأسنان التي تباع حاليا في السوق الليبي. تم تحليل 30 علامة تجارية مختلفة من منتجات معجون الأسنان (9 للأطفال و21 للبالغين) لتقييم تركيز الفلوريد فيها. استخدمت الطريقة الطيفية لتقييم تركيز الفلوريد. وأظهرت النتائج أن جميع عينات معاجين الاسنان الموصوفة للأطفال التي تم اختبارها والبالغ عددها تسع عينات تحتوي على مستوى الفلوريد أقل من 500 جزء في المليون وهو ما يناسب الأطفال. في المقابل، كان تركيز الفلوريد في 18 عينة (85.7%) من معجون الأسنان للبالغين يتراوح بين 500 و1500 جزء في المليون. وتجاوزفي ثلاث عينات (14.3%) الحدود الموصى به حيث بلغ تركيزه أكثر من 2000 جزء في المليون. يمكن الاستنتاج أن محتوى الفلوريد في معجون أسنان الأطفال كان ضمن المستويات المثالية الموصى بها. في حين ان هناك تباين واسع في تركيز الفلوريد للعينات الأخرى .

الكلمات المفتاحية: مقياس الطيف الضوئي، طريقة*SPADNS* ، غسولات لأسنان، الفلورايد، معجون الأسنان.

Introduction

Fluoride (F−) is a significant anion in various environmental, clinical, and food samples. While small quantities of fluoride are essential for the human body, excessive amounts can be toxic (Sara & Perham 2024). After extensive research, it became evident that fluoride exposure to humans was not solely limited to drinking water, contrary to previous beliefs (Chowdhury et al, 2019 Kumar et al, 2020). Fluoride enters the human body through the mouth. Following ingestion, it is rapidly absorbed into the blood plasma, predominantly in the stomach, and then distributed from the plasma to human tissues and organisms. Excessive intake of fluoride leads to many health issues, including fluorosis, thyroid disease, neurological issues, and osteoporosis (Doull et al., 2006). It is essential to recognize that it may also inhibit the activity of various vital enzymes. (Adejoumo et al, 2009).

Fluorides are frequently used in oral hygiene products because they effectively prevent tooth decay (Davies et al., 2004). Fluoride is useful for dental health as it helps to prevent tooth decay by improving remineralisation and altering the tooth structure, which makes the tooth surface less susceptible to dissolution. Different countries use various fluoride concentrations in toothpaste, which is considered safe for oral health and general use by consumers (De Almeida et al., 2007). Broadly, in different parts of the world, toothpaste's maximum permissible fluoride levels ranged from 100 to 1,500 ppm (Lacsou et al., 2021). Dental fluorosis is more susceptible to kids and is a common disease in a large number of individuals. Fluoride was added to toothpaste as sodium fluoride or sodium monofluorophosphate (Giacaman et al., 2013).

Fluoride toothpaste is crucial to any oral health regimen to prevent tooth decay (Berger et al, 2022). Toothpaste has evolved to serve multiple purposes beyond just cleaning teeth; it contains various additive components for health and cosmetic reasons, such as to prevent tooth decay, colourants, flavours, and preservatives. Fluoride in toothpaste can be found in ionic or nonionic forms. The effectiveness of fluoride in toothpaste in preventing dental caries depends on the bioavailability of ionic fluoride. It has been observed that the level of soluble ionic form decreases over time by interactions with other ingredients in the toothpaste (Pillai et al, 2022). Toothpaste is classified as a drug, so the fluoride levels must be controlled carefully and measured accurately. Therefore, this study aims to assess the fluoride level of commercially available toothpaste in Libyan markets.

Materiel and method

Fluoride concentration was determined by various methods, which include potentiometric, spectro-photometry, chromatography, and electrochemical methods (Ermer & Miller, 2005). The present study used the spectrophotometric SPADNS method [sodium 2-(parasulfophenylazo)-1,8-dihydroxy-3,6-naphthalen di sulfonate]. A spectrophotometric analysis of the fluoride level in toothpaste was determined as described by (Rice, 2012). Briefly, 500 ml each of 0.191% SPADNS and 0.0266% of Zirconyl acid were prepared. Reference solution prepared by combining 10 ml of SPANDS solution with 90ml distilled water, followed by adding 7 ml of concentrated HCl. This resulting solution used to calibrate the spectrophotometer.

Fluoride standards (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, and 1.4 mg/l) were prepared by diluting a standard fluoride solution to 50 ml with distilled water and adding 10 ml of SPANDS-Zirconyl to each standard. Spectrophotometer was zeroed with the reference solution; the absorbance of the standard solutions was taken at a wavelength of 570 nm. A calibration curve of the microgram fluoride against absorbance relationship was plotted based on these readings.

Toothpaste samples were purchased from local markets, in different brands, and countries of origin. One g of toothpaste from each sample was weighed and dissolved in 100 ml of distilled water. The solution was then filtered, and the filtrate was used to test free fluoride using the SPANDS-Zirconyl acid reagent mentioned above and the calibration curve.

Result

A total of 30 different toothpaste products were purchased from the Libyan local market and analyzed using the spectrophotometric method to determine the fluoride concentration. The obtained results were divided into three tables according to the range of fluoride concentration and reported as (µg/ml).

Table 1: Fluoride concentration in children's toothpaste (µg/ml).

Sample code	Brand	Country manufactured	Fluoride conc. (µg/ml).
n1	Signal	Egypt	400
n2	Mlswak	Egypt	230
n3	Sensodyne	U E	220
n4	Sensodyne	France	100
n5	Colgate	U.S.A	300
n6	Dentakleen	China	140

n7	Cariax kin	Spain	338
n8	Sensodyne	U.S.A	250
n9	Colgate	Poland	150

Table 2: Fluoride concentration in adult toothpaste ranged between (500 – 1500 µg/ml).

Sample code	Brand	Country manufactured	Fluoride conc. (µg/ml).
n10	Signal	I.R	1400
n11	Oral-B	U.K	700
n12	Sensodyne	Slovakia	600
n13	Sensodyne	U.K	1000
n14	Sensodyne	I.E	500
n15	Colgate	Poland	500
n16	Crest	Germany	600
n17	Colgate	K.S.A	500
n18	Oral-B	Germany	520
n19	Colgate	China	1500
n20	Aqua	Egypt	1200
n21	Parodontax	France	900
n22	Signal	Singapore	1500
n23	Aqua Fresh	Egypt	500
n24	Signal	K.S.A	550
n25	Signal	U.K	550
n26	Colgate	India	1400
n27	Signal	France	969

Table 3: The fluoride concentration of adult toothpaste at a range of 1500 µg/ml.

Sample code	Brand	Country manufactured	Fluoride conc. (µg/ml).
n28	Close up	Vietnam	2100
n29	Crest	Germany	2140
n30	Colgate	China	2400

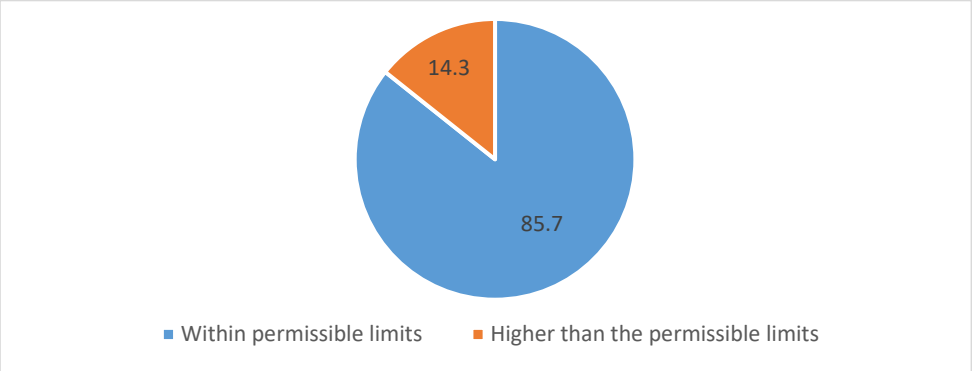

Figure 1. The percentage within permissible limits and Higher than the permissible limits of toothpaste fluoride content.

Discussion

It is evident that this study holds significance in assessing the fluoride content of commonly used toothpaste products. The findings revealed that the fluoride content in toothpaste indicated for children closely matched the optimal level of 500 ppm, as indicated in Table 1. This aligns with previous studies by Borremans et al. (2008) and Hastuti et al. (2013), which also reported a fluoride concentration of 500 ppm in toothpaste intended for children.

For the samples in Table (2) and Table (3), there was a significant difference in the fluoride concentration found in the various toothpaste products available in different regions of the world. The results show 85.7% within the permissible limits of fluoride. In comparison, 14.3% higher than the permissible limits in Figure (1), and these results are similar to those of the study conducted by Adejumo et al. (2009; Cury et al.,2010; Carrera et al., 2012).

According to a study by Cury et al. (2010), it is widely recognized that the fluoride content in toothpaste diminishes over time as a result of the interaction between the abrasives and the fluoride compound. It

is possible that manufacturers do not specify the exact fluoride concentration in their product labels. Fluoride toothpaste, usually around 1500 ppm fluoride, is still the most common and effective way to prevent tooth decay in modern society (Walsh et al., 2019). However, excessive fluoride consumption can result in a condition known as fluorosis. Different levels of fluorosis become apparent depending on the amount and regularity of fluoride consumption. T
he fluoride accumulation in teeth can lead to decreased protease activity, causing abnormal changes in the enamel structure. The decay of dental pulp cells causes discoloration and irregular lesions on the surface of the teeth. This process has been discussed in Mondal Chattopadhyay's (2020) and Vandana et al. (2021) studies. Exposure to high fluoride levels over a long period can lead to skeletal fluorosis, a condition characterized by the accumulation of fluoride in the bones and increased bone density (Srivastava & Flora, 2020). The ingestion of fluoride has been described as a "double-edged sword," as it can have both beneficial and harmful effects on human health (Zhang et al., 2020).

Conclusion

The effectiveness of fluoride in toothpaste in preventing dental caries depends mainly on the bioavailability of ionic fluoride. It is important to note that the study only measured the total fluoride concentration and did not specifically assess the ionic fluoride content in the toothpaste. As a result, it is strongly recommended that future studies focus on evaluating both the ionic and nonionic fluoride concentrations in toothpastes available in Libyan markets.

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