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ASSESSMENT OF HYDROQUINONE IN SKIN WHITENING FORMULATIONS

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Abstract
Exposure of hydroquinone (HQ) through the skin whitening cream may cause serious skin allergic problems. The use of hydroquinone in cosmetic is banned in many European countries however, its use in developing countries is still common as depigmenting agents. This study was conducted to estimate the concentration of hydroquinone in twenty different cosmetic products by using UV-visible spectrophotometer. The method showed excellent linearity (0.9998) in the concentration range of 0.5 to 50 µg/mL. The results showed that 6 out of 20 samples (30%) contained detectable levels of hydroquinone in the range of 0.08% to 0.92 % w/w with mean concentration 0.36 % w/w. None of the sample exceeded the permissible limit of 2% w/w. These findings highlight significance of regular monitoring of cosmetics products to protect public health.

1. INTRODUCTION

In many south Asian countries, skin whitening also known as skin lightening or bleaching is a the most common cosmetic procedure to look attractive (Ludidi, 2019). The desire for a paler complexion in Pakistan stems from cultural beliefs that link lighter skin to social standing and beauty (Khan et al., 2021). The sale of Skin-whitening products make up over 30% of all cosmetic in Pakistan whereas, the cosmetics industry is valued at over 1 billion dollar (Naveed, 2025). Due to the this over demand, both approved and unregistered skin-whitening products containing higher amount of the hydroquinone (HQ) and other toxic chemicals have proliferated in marketplaces.

Hydroquinone (1,4-dihydroxybenzene; C6H4(OH)2) is an aromatic chemical molecule, competitively bind and prevent the conversion of L-tyrosine to L-DOPA which inhibits tyrosinase, an enzyme required for melanin formation in melanocytes and act as topical depigmenting agent (Fabian et al., 2023; Palumbo, d'Ischia, Misuraca, & Prota, 1991).

Despite being the gold standard for treating melasma and hyperpigmentation for a long time, hydroquinone's safety profile has come under intense regulatory and scientific examination recently (Beaumet & Haudecoeur, 2025) Exogenous ochronosis (EO) an irreversible illness that causes hyperpigmentation has been linked to HQ uses in cosmetics. Furthermore, Short-term effects include contact dermatitis and erythema also have been reported (Passeron & Ortonne, 2024; Schwartz, Jan, & Zito, 2023) Due to its toxicity, many regulatory agencies have limited or outright prohibited the use of hydroquinone in cosmetics. The FDA restricts its use to prescription formulations containing no more than 4% w/w, while the European Union outlawed it by Cosmetics Regulation (EC) No 1223/2009(Radhika, Sharvani, Hemanth, & Prasanthi, 2025). The WHO recommends a maximum cosmetic concentration of 2% w/w(Organization, 1994). In Pakistan, PSQCA standard PS 3228-2017 explicitly prohibits hydroquinone in skin creams

(PSQCA, 2017), yet enforcement remains inadequate and non-compliant products persist widely in markets (Arshad et al., 2021). Therefore, this study was conducted to estimate hydroquinone concentrations in commercially available Pakistani skin whitening cosmetics using HPLC-UV method, and to assess regulatory compliance against national and international safety standards.

2. Materials and Methods

2.1. Chemicals and Reagents

Hydroquinone and methanol purchased from Sigma-Aldrich (St. Louis, MO, USA) and all other reagents used were of analytical grade. A standard stock solution of hydroquinone (1000 µg/mL) was prepared in methanol. Working standard solutions in the concentration range of 2 to 40 µg/mL were prepared by appropriate serial dilution in methanol.

2.2. *Sample Collection and preparations*

A total of twenty skin whitening cosmetic samples were collected from various retail markets. The sample set included twelve cream-based formulations, five lotions, and three serums. Products were selected to represent both locally manufactured brands and imported formulations that are commonly available in Pakistani markets. Each sample was assigned a unique code (S1 through S20) and stored at room temperature in their original packaging until analysis.

An accurately weighed 1.0 g portion of each cosmetic sample was transferred to a 25 mL volumetric flask and 15 mL of methanol was added, and the mixture was sonicated for 30 minutes at 25°C to ensure complete extraction of hydroquinone (Khoshneviszadeh, Bazzaz, Housaindokht, Ebrahim-Habibi, & Rajabi, 2015). After sonication, the volume was adjusted to the mark with methanol and mixed thoroughly. The resulting solution was centrifuged at 4000 rpm for 15 minutes. The supernatant was filtered and appropriately diluted with methanol to bring the concentration within the working range prior to spectrophotometric measurement. (Karnelasatri, Tahya, Adila, Hardy, & Munthe, 2024).

2.3. UV-Visible Spectrophotometric Instrumentation and Conditions

Spectrophotometric analysis was performed using a UV-Visible double beam spectrophotometer equipped with 1 cm quartz cuvettes (Perkin Elmer). The maximum absorption wavelength (λmax) of hydroquinone in methanol was determined by scanning a 20 µg/mL standard solution over a wavelength range of 200–400 nm found at 293 nm, in agreement with the United States Pharmacopeia (USP) and reported in many studies (Khoshneviszadeh et al., 2015; Rashid et al., 2022)

3. Results and Discussion

3.1. Method Validation Results

Validation of the UV-visible spectrophotometric method was performed for hydroquinone in accordance with ICH Q2(R1) guidelines, and the performance characteristics are summarized in Table 1. A linear calibration curve was obtained over the concentration range of 2 to 40 µg/mL with a correlation coefficient of R^2 = 0.9996, confirming excellent linearity within the working range. The calibration data points, observed absorbance values, and the regression equation A = 0.0213C + 0.0041 are presented in Figure 1.

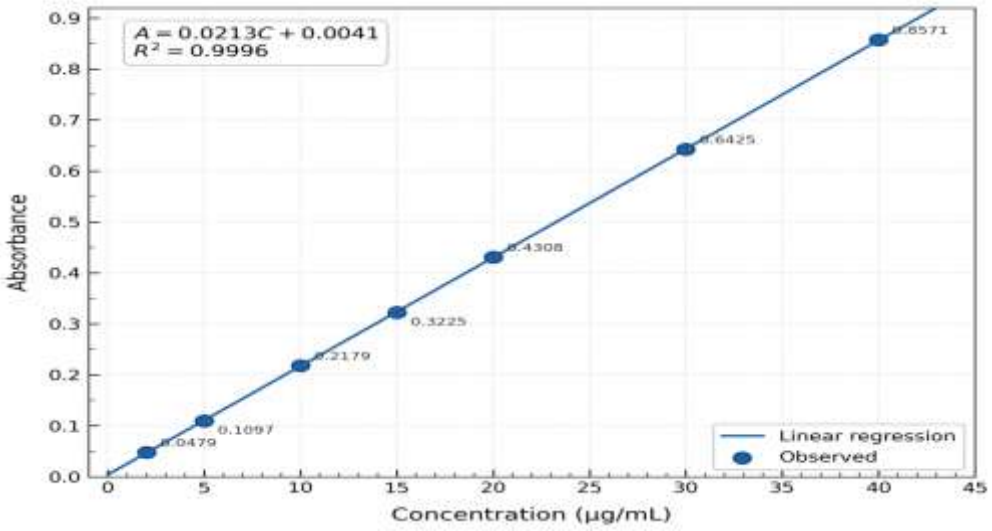

Figure 1: Calibration curve for HQ in cosmetics

The accuracy of the method expressed as percent recovery was found in the range 98.4% to 101.8% which falls within the range of specified by ICH guidelines(ICH, 2005). The LOD and LOQ were calculated to be 0.15 µg/mL and 0.46 µg/mL, respectively. These validation results are consistent with previously reported UV-spectrophotometric methods for hydroquinone analysis in cosmetic and pharmaceutical formulations (Khoshneviszadeh et al., 2015).

Table 1. Summary of UV-Visible Spectrophotometric Method Validation Parameters

Parameter	Result
Linearity Range	2 – 40 µg/mL
Correlation Coefficient (R^2)	0.9996
Regression Equation	A = 0.0213C + 0.0041
LOD	0.15 µg/mL
LOQ	0.46 µg/mL
Mean Recovery	100.1%
Detection Wavelength (λmax)	293 nm
Solvent	Methanol

3.2. Determination of Hydroquinone

Analysis of twenty commercially available skin whitening cosmetics revealed that only six out of twenty samples (30%) contained detectable levels of hydroquinone, while the remaining fourteen samples (70%) showed no detectable hydroquinone despite carrying labeling claims suggestive of skin whitening or lightening activity (Table 2). The absence of hydroquinone may be indicative of the adoption of alternative depigmenting agents such as kojic acid, arbutin, or niacinamide. Among the six HQ-positive samples, concentrations were in found in the range of 0.08% w/w to 0.92 % w/w with a mean concentration of 0.36% w/w. Importantly, none of the analyzed samples exceeded the WHO-recommended maximum permissible limit of 2% w/w. This low values in hydroquinone are may be due to PSQCA standard PS 3228-2017 which prohibit the use of HQ in cosmetics (PSQCA, 2017).

The results found here are consistent with the previous studies conducted in Pakistan. Arshad et al. has analyzed 20 fairness creams by using HPLC, found HQ concentrations in the range of 0.12% to 7.2% w/w indicating higher concentration of HQ as compared to found here (Arshad et al., 2021). This divergence reflects differences in sample selection criteria, geographic sampling location, and the types of

products targeted. In another study conducted on 22 skin-whitening products via TLC and HPLC found hydroquinone in 11 cosmetic products in the range of 0.002% to 0.092% w/w (Majeed, Shah, & Anjum, 2021; Siddique, Parveen, Ali, & Zaheer, 2012).

The large number of manufactures of these products in Pakistan are unauthorized and working illegally on a large scale. A report published in 2018 by a joint effort of the Ministry of Climate Change and the Sustainable Development Policy Institute, Islamabad, Pakistan, found 56 out 59 local and international brand had excessive amounts of toxic compounds (Reporter, 2020). A report published by BBC, many beauty creams contained prohibited chemicals such as hydroquinone, mercury, or corticosteroids as core ingredients despite its prohibited use in cosmetics These reports shows that use of HQ in beauty cream is most common(Ahmed, 2017; Khan et al., 2021). The use HQ in skin related products not only in Pakistan but also reported from many international studies. Alshammari et al found HQ in 80% of tested skin-lightening cream samples and found maximum concentration up to 7.1% (Alshammari et al., 2025).

Table 2. Hydroquinone in Skin Whitening Cosmetic

Sample Code	Product Type	HQ (% w/w)	Compliance (WHO ≤2%)
S1	Cream	0.45	Compliant
S2	Cream	0.92	Compliant
S3	Lotion	ND	–
S4	Cream	ND	–
S5	Serum	0.13	Compliant
S6	Cream	ND	–
S7	Lotion	0.08	Compliant
S8	Cream	ND	–
S9	Cream	ND	–
S10	Serum	ND	
S11	Lotion	ND	–
S12	Cream	ND	–
S13	Cream	ND	–
S14	Cream	0.25	Compliant
S15	Lotion	ND	–
S16	Serum	ND	–
S17	Cream	0.33	Compliant
S18	Cream	ND	–
S19	Lotion	ND	–
S20	Cream	ND	–

4. Conclusion

UV-Visible spectrophotometer based method was successfully applied to determine the HQ in twenty skin whitening cosmetics available in local market of Hyderabad Pakistan. HQ was found in six sample within the range of 0.08% to 0.92 % w/w and mean concentration 0.36 % w/w. None of the sample has exceeded WHO recommended maximum permissible limit of 2% w/w. These findings are consistent with previous studies conducted in Pakistan and highlight the need for regular monitoring of these cosmetic products to ensure public safety.

Conflict of interest

Author declares no conflict of interest

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