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Original Article

Medicated Kajal Ophthalmic Nanoparticulated Drug Delivery System

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ABSTRACT

Background: Kajal has been used for ages as a cosmetic and to cure eye conditions in India. In order to improve therapeutic efficacy and ocular safety, we create a herbal medicated kajal with optimal extraction, formulation, and evaluation. Novel herbal medicated kajal and *in situ* gel formulation were developed using natural ingredients, with *Areca catechu* extract as the key active component. Important herbal components such Ghee, Bhimseni Camphor, Dry Coconut, Nutmeg, and *Areca catechu* nut were used in formulation. **Objectives:** This current study shows the development of formulations, evaluation and determination of drug content in formulation. **Materials and Methods:** Ethanolic extraction of dried *Areca catechu* by using cold maceration method was followed by formulation development. Carbon filaments prepared by using Ghee, Bhimseni Camphor, Dry Coconut, Nutmeg were collected, evaluated and used for preparation of kajal and *in situ* gel with *Areca catechu*. Developed kajal and *in situ* gels formulations were evaluated as per official guidelines. **Results:** Collected carbon filaments were evaluated with different parameters. Prepared carbon show satisfactory flow properties and compatibility. Two formulations were developed with these carbon filaments. All QA/QC parameters of kajals and gels were performed as per official methods. Spectrophotometric analysis confirmed uniform drug content with high linearity (R^2=0.998) across the tested range. **Conclusion:** The kajal and *in situ* gel prepared with ghee and *Areca catechu* was found to be better in quality as compared to other formulations prepared with other herbal materials. Hence it can conclude that nanoparticulated ophthalmic formulation prepared from untapped drug were found to be stable and standardized.

Keywords: *Areca catechu*, Kajal, *In situ* Gel, Ophthalmic Formulation, UV Spectroscopy.

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INTRODUCTION

Kajal, traditionally known as Surma or Anjanum, has held a prominent place in Indian cultural and medicinal practices for centuries. Its significance is deeply rooted in classical Ayurvedic texts such as the Charaka Samhita and Sushruta Samhita, where it was valued not only for its cosmetic appeal but also for its therapeutic benefits. Kajal was commonly used to treat various eye disorders, including Abhishyand (conjunctivitis), Adhimanth (glaucoma), and Timir (cataract). Its application was believed to protect the eyes from infections and environmental irritants like dust and smoke. Beyond its medicinal role, kajal also carried spiritual importance it was often applied as a safeguard against negative energies and the "evil eye," especially in infants and during auspicious occasions (Khakre *et al*., 2024).

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Medicated kajal is traditionally applied to nourish eyes that are stressed, raw, or mildly injured. It provides a cooling effect that soothes discomfort and supports overall eye wellness. The formulation also acts as an anti-inflammatory agent and is used to manage symptoms such as eye redness and itching, reflecting its gentle therapeutic role in traditional eye care practices (Varpe *et al*., 2022).

Areca catechu Linn., commonly referred to as betel nut, is a slender palm belonging to the Arecaceae family. It is widely cultivated across South-East Asia and various regions of India, particularly along the coastal belts from Maharashtra to Kerala and Tamil Nadu, as well as in the Deccan plateau, Assam, Meghalaya, West Bengal, and the Andaman and Nicobar Islands, thriving in moist tropical climates. The areca nut refers to the deep reddish kernel of the fruit and is traditionally recognized for its therapeutic roles, including use as a chewing stimulant, a remedy for intestinal parasites, an aphrodisiac, and in regulating blood pressure (Bhandare *et al*., 2010).

Bhimsen camphor is a naturally occurring crystalline substance derived from organic sources. Renowned for its purity, it is widely used in both medicinal applications and spiritual rituals.

This form of camphor is recognized by various regional names, including pacha camphor and desi Kapoor. It is extracted through the distillation of bark and wood from the *Cinnamomum camphora* tree, a species native to East Asia-particularly China, Taiwan, Japan, and Vietnam. Over time, cultivation of these camphor trees has expanded to other regions with tropical and subtropical climates, such as India, Sri Lanka, Madagascar, South Africa, and the United States. For centuries, Bhimsen camphor has been valued across cultures for its therapeutic properties. Traditionally used to alleviate a wide range of ailments, including inflammation, infections, respiratory congestion, pain, and skin irritation, it remains a trusted natural remedy. Its versatility lies in its ability to be absorbed through the skin, as well as administered via inhalation or oral ingestion, making it effective in multiple forms of treatment (Pawar and Sarvadnya, 2023).

Myristica fragrans, commonly known as nutmeg or mace, is an aromatic evergreen tree from the Myristicaceae family. It bears yellow, fleshy fruits resembling apricots and is native to regions like India, Southeast Asia, Northern Australia, and the Pacific Islands. The main components of *Myristica fragrans* include alkyl benzene compounds like myristicin, elemicin, and safrole, along with terpenes, alpha-pinene, beta-pinene, myristic acid, and trimyristin. Myristicin is a natural flavouring substance and is known to have strong effects on the nervous system. Mace contains 8-17% volatile oil, as well as fixed oil, resin, fat, sugar, dextrin, and mucilage. Nutmeg exhibits a wide range of pharmacological properties, including antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, aphrodisiac, anti-diabetic, and memory-enhancing effects (Verma *et al*., 2023).

Benefits of Applying Kajal

While applying Kajal, the eyelids of the eyeballs get a massage which increases the blood circulation of eyes and hence, improve eye sight.

- It protects eyes from sharp rays of sun,
- It moisturizes the eye,
- It helps to make the little red vessels in the eyes disappear so that they remain white,
- Kajal helps to remove dirt and dust, and relives watering and burning of eyes due to strain,
- Kajal has refreshing, Astringent and Disinfectant properties (Varpe *et al*., 2022).

Nanotechnology has opened a window for the development of diverse organic and inorganic drug carriers, known as nanoparticles. Nanoparticles are generally <1000 nm. They have an ultra-small size, large surface area to mass ratio, and high reactivity, which are different from bulk materials of the same composition; in addition, they are able to adsorb or conjugate with a wide variety of therapeutic molecules (Lamberti *et al*., 2015).

Cosmeceuticals are cosmetic products with biologically active ingredients purporting to have medicinal or drug like property, Nowadays Cosmeceuticals are the fastest developing part of natural personal care industry, extensive use of chemically derived cosmetic products harm the skin permanently. This awareness increases the demand of Ayurveda or organic herbal cosmetics which itself have drug like effect (Mishra and Mishra, 2016).

Nanoparticles provide great advantages for CNS and ocular drug delivery by favorably altering the Pharmacokinetics while at the same time maintaining the therapeutic effects of the substance. The mechanism and transport efficiency of nanoparticles across the barriers are dependent on the physicochemical properties of the nanoparticles, such as particle size, charge, surface ligands, and hydrophobicity. Safety of the nanoparticles, including the biocompatibility and the biodegradability, is also crucial in designing the delivery vectors. This section will highlight the desired physicochemical properties of nanoparticles for effective CNS and ocular delivery (Zhang *et al*., 2016).

MATERIALS AND METHODS

Preparation of Ethanolic Extract of *Areca catechu*

1000 g of dried *Areca catechu* was extracted with 50 mL of Ethanol by cold maceration technique keeping it at room temperature till solvent coming from it become Colourless. Then filter the extract using whatman filter paper. Make the extract solvent free by using rotary vacuum evaporator keeping temperature in the range of 30-40°C. A dark Brown residue obtained having characteristic odour. Further remaining solvent is evaporated to dryness by using vacuum oven (Asrianto *et al*., 2022; Ansari *et al*., 2021; Ramya *et al*., 2021; Zhang *et al*., 2014).

Collection of carbon filament from Ghee

Carbon filaments were prepared from Ghee, Bhimseni Camphor, Dry Coconut, Nutmeg collected from market which consists of four steps given in Figure 1.

This procedure was used for collecting carbon filament ffrom Bhimseni Camphor, Dry Coconut, Nutmeg. In first step Bhimseni Camphor, Dry Coconut, Nutmeg were directly burned (Jaiswal *et al*., 2024; Shukla *et al*., 2022; Liu and Ma., 2021; Adeyemi and Onianwa., 2017; Wang *et al*., 2022).

Analysis of Carbon Filament

Determination of Physical Constant of Carbon Filaments

Solubility: Solubility of carbon filaments was performed as per official method (Sumit *et al*., 2023; Umpa and Suwanmala., 2018; Neto *et al*., 2023; Li *et al*., 2021).

Bulk Density, Tapped density and Angle of repose

Bulk Density is a characteristic of a powder rather than individual particles. An accurately weighed quantity of carbon filaments was transferred into 50 mL measuring cylinder with the aid of the funnel. The unsettled apparent volume, to the nearest graduated unit occupied by the carbon filaments was measured. After 50 tapings of the same quantity of powder, the taped density was determined. Angle of repose of collected carbon filaments was determined by the funnel method. The carbon filaments were allowed to flow through the funnel freely onto surface. The diameter of the powder cone was measured and angle of repose was calculated (Shah *et al.*,2018; Ramachandran *et al.*, 2020; Sumit *et al.*, 2023; Li *et al.*, 2021).

Prepration of Kajal

The kajal were prepared indiviusally of all the collected black soot. In 500 mg of carbon filament were taken, 5 mg Areca catechu extarct was added individually. The prepared powder was mixed with cow ghee and traturate well to form kajal, See Table 1 and Figure 2 (Sharma *et al.*, 2022; Gupta *et al.*, 2024; Patel *et al.*, 2025; Kashyap *et al.*, 2021).

Analysis of Kajal

The prepared Kajals were tested for spredability, smoothness and non stickiness.

Determination of % Drug Content

In 10 mg of kajal 6 mL of methanol was added and the solution was sonicated. Solution was heated for 2 min and filter with unhydrous sodium sulphate. Further washing was given with 6 mL methanol, fiter it and evaporate the filtrate. In dry mass add ethyl acetate to make up the volume upto 3 mL (Kajal Breaking Solution).

Spectroscopic Evaluation of Kajal Breaking Solution

0.1 mL of Kajal Breaking solution individually dissolved in 10 mL of Ethyl Acetate and this solution was scanned between 200-600 nm in a double beam UV Spectro Photometer [Shimadzu 1800] (Gujar *et al.*, 2024; Chaudhari *et al.*, 2024; Sonawane *et al.*, 2025; Alamu *et al.*, 2020).

Prepartion of *in situ* Gel

The polymeric solution was prepared by dispersing required quantity of sodium alginate as main polymer and HPMC - E50LV, HPMC - K4M as co- polymer in disttiled water using magnetic stirrer until the polymers completely dissolved. Mix the carbon filaments and Betal Nut dry extract well. To this polymeric solution was added with continous strring until the drug completely dissolved in polymeric solution. The pH of solution was adjust to 6.5 using 0.1NaOH, See Table 2 (Mandal *et al.*, 2003; Malathi *et al.*, 2024; Rahaman *et al.*, 2024).

Table 1: Formula for *Areca catechu* Kajal.

Sl. No.	Ingredients	Quantity Taken
1	Carbon Filament	500 mg
2	*Areca catechu* Extract	5 mg
3	Cow ghee	q.s.

Analysis of *in situ* Gel

The prepared *in situ* gel solution was tested for Spredability and pH.

Rehological Studies

The viscosity mesurment of *in situ* gel were carried out using Brookfield Viscometer. The formulation were placed in the sample tube. The sample were analysed by circulating batch connected to the viscometer adaptor prior to each mesurment. The angular velocity of the spindle was increased 1to 4 and the velocity of the formulation was mesured (Kumar *et al.*, 2019; Singh *et al.*, 2025; Shastri *et al.*, 2023).

Determination of Drug Content

Determination of λ_{max} of Kajal

0.1 mL Kajal breaking solution was dissolved in 10mL Ethyl Acetate individually. This solution was scanned between 200 nm to 400 nm in a double beam UV spectrophotometer [Shimadzu 1800].

Determination of λ_{max} of *in situ* Gel

1 mL of gel dissolved in 10 mL of distilled water and filter with wathmen filter paper. Then 0.1 mL filtrate solution was dissolved in 10 mL of distilled water. This solution was scanned between 200 nm to 400 nm in a double beam UV spectrophotometer [Shimadzu 1800] (Jain *et al.*, 2023; Raut *et al.*, 2022; Dias *et al.*, 2023).

RESULTS

Methanolic extract of *Areca catechu* was found to powdery, brown in color and having characteristic odor.

Table 2: Formula for Ophthalmic *in situ* Gel.

Sl. No.	Ingredients	Quantity Taken
1	Betal Nut Extract	5 mg
2	Carbon filaments	5 mg
3	Sodium alginate	0.25 g
4	HPMC - E50LV	0.75 g
5	HPMC - K 4M	0.25 g
6	Distilled water	Upto 50 mL

Determination of Physical Constant of Carbon Filaments

The prepared carbon filaments were found to be smooth and satisfactory. The Table 3 provides a summary of the solubility findings.

Flow property of carbon filaments

The prepared carbon filaments shows good flow property, which was evaluated by determining bulk densities in a range of 0.9 to 0.98 g/cm^3, tapped density in a range of 0.94 to 0.96 g/cm^3. Good flowability was shown by the carbon filaments average angle of repose, which was found to be 30^o. The results of findings were summarized in Table 4.

Table 3: Solubility of carbon filaments

Sl. No.	Solvent	Solubility
1.	Distilled water	Poorly soluble
2.	Ethanol	Soluble
3.	Methanol	Soluble
4.	DCM	Poorly soluble
5.	N- Hexane	Soluble

Evaluation of Kajal

Appearance: All prepared Kajal was observed smooth and shiny in Appearance.

Evaluation of ophthalmic *In situ* Gel

The prepared ophthalmic *In situ* gels with the help of polymer and co-polymers were clear and found to be good in quality. pH plays an important role in therapeutic activity, solubility, stability and comfort to the patient. pH of all *In situ* Gels are within limit. The size of drop and its residences in eyes depends on the viscosity of formulation. In order to prolong the contact time of the drug in the eye, various thickening agents are added in the ophthalmic preparation. The average viscosity was found to be 28.8 Pa·s. The spreadaibility testing of kajal involves measuring the time it takes for a specific amount of kajal to spread to a certain thickness under a defined weight. This test assesses the ease with which the kajal can spread evenly. The spreadability test demonstrated that the kajal could be applied smoothly and evenly, essential for consumer satisfaction, ensuring uniform delivery of active ingredients. The spreadability test is crucial for evaluating the texture and consistency of the kajal, ensuring it can be applied smoothly and uniformly. The results of findings were summarize in Table 5.

Table 4: Flow Properties of Carbon Filaments

Sl. No.	Parameters	Ghee	Camphor	Coconut	Nutmeg
1.	Angle of repose (^{0})	31	28	31	30
2.	Bulk Density (g/cm^3)	0.95	0.98	0.98	0.9
3.	Tapped Density (g/cm^3)	0.96	0.95	0.95	0.94

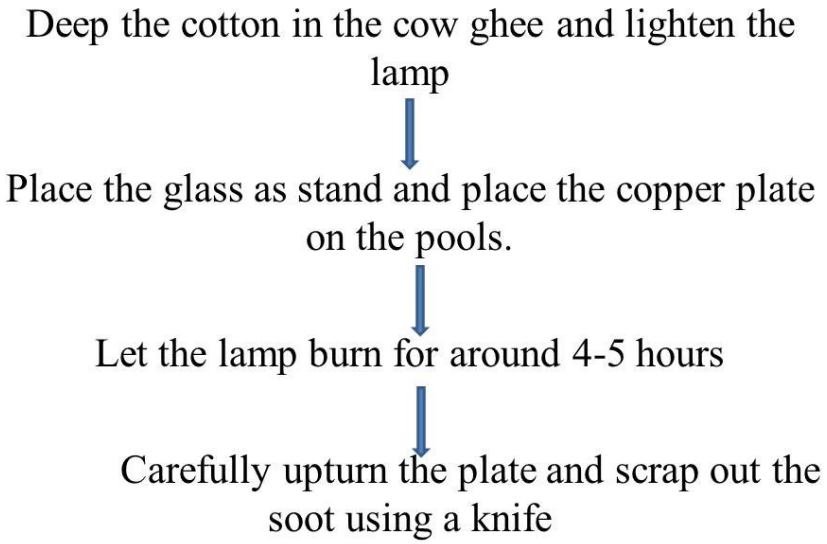

Figure 1: Traditional Carbon Filaments Collection.

Determination of Drug Content

For quantification purpose the *Areca catechu* extract used in formulation was standardized by UV visible Spectroscopy with analytical markers, Ellagic acid and Gallic acid. The results was summarise in Table 6.

By UV visible Spectrophotometry

Standardization of Extract using Analytical Marker.

of Formulations Using Analytical Markers

Standardized extract was used in formulations and prepared formations were standardized with analytical markers. The percent drug content for kajal and *In situ* gel was determined and result was mentioned in Table 7.

DISCUSSION

Medications Kajal was considered a revolutionary cosmeceutical formulation for combating eye infections and enzymes, as kajal is highly effective in skin makeup. In the current study, the goal was to develop a modern formulation of preliminary Ayurvedic kajal, known as soot or lamp black, using herbs, with consistent identity and physical evaluation. For this work, *Areca catechu* was extracted using a simple maceration method with ethanol as a solvent. The ethanolic extract of *Areca catechu* was dark brown and had a characteristic odor. Various raw materials such as cow ghee, Bhimseni camphor, coconut, and nutmeg were chosen to prepare carbon filaments. To characterize the carbon filaments tests including solubility and powder flow properties like angle of repose, bulk density and tap density were conducted and found satisfactory. Kajal was prepared using the collected carbon filaments and *Areca catechu* extract, with each raw material contributing beneficial properties to the formulation. After preparation, the kajals were evaluated using various parameters. Additionally, an *in situ* gel formulation was created by incorporating *Areca catechu* extract and carbon filaments, where the carbon filaments acted as carbon nanotubes providing a coating that controls drug release. All quality assurance and quality control tests for the gels were performed according to official methods and gives satisfactory results. Drug content was determined using UV-visible spectroscopy. Among the formulations, the kajal made with ghee and *Areca catechu* showed superior quality compared to those prepared with other herbal materials. The extract was standardized using analytical markers such as gallic acid and ellagic acid, and the formulations were standardized accordingly. The development of a medicated herbal kajal using *Areca catechu* nut extract demonstrated promising outcomes, supporting its potential as a cosmetic product with added therapeutic benefits. This study contributes

Table 5: Evaluation of *In situ* Gel

Sl. No.	Formulations	pH	Viscosity	Spreadability
1.	Betal Nut+Ghee Gel	6.4	28.0	Good
2.	Betal Nut+Camphor Gel	6.5	30.3	Good
3.	Betal Nut+Coconut Gel	6.5	28.60	Good
4.	Betal Nut+Nutmeg Gel	6.5	28.2	Good

*Ghee = Carbon filament of ghee.

Table 6: Standardization of Extract by Analytical Marker

Sl. No.	Extracts	Marker	% Assay	RSD
1.	Betal Nut	Ellagic acid	0.12	0.11
		Gallic acid	0.16	0.04

Table 7: Formulation Standardisation

Sl. No.	Crude drug	Marker	Kajal		*In situ* gel	
			% Assay	RSD	% Assay	RSD
1.	Ghee	Ellagic acid	16.01	0.12	10.58	0.23
		Gallic acid	10.01	0.48	10.72	0.34
2.	Camphor	Ellagic acid	6.87	0.10	13.12	0.17
		Gallic acid	4.83	0.22	10.01	0.22
3.	Coconut	Ellagic acid	5.04	0.5	8.47	0.11
		Gallic acid	7.09	0.20	10.24	0.16
4.	Nutmeg	Ellagic acid	7.11	0.19	7.31	0.20
		Gallic acid	9.18	0.26	7.64	0.27

Figure 2: Kajal prepared with Ghee, Dried coconut, Nutmeg and Bhimseni Camphor.

to the expanding field of herbal cosmetics, emphasizing the value of combining traditional knowledge with modern scientific methods to create innovative and effective products.

CONCLUSION

This study aimed to create a medicinal herbal kajal utilizing *Areca catechu* nut extract as a primary component, focused on generating a safe and efficient cosmetic product. The formulation method utilized conventional and scientifically proven techniques to blend *Areca catechu* nut extract with various advantageous herbal components. In the current study, different raw materials like Cow ghee, Camphor, Coconut, and Nutmeg were utilized as sources of Carbon. These raw materials possess unique therapeutic properties beneficial for formulation, and the gathered carbon filaments from these sources function as Carbon Nanotubes. Therefore, it can be concluded that the nanoparticulated ophthalmic formulation made from an unexploited drug was determined to be stable and consistent. It can be demonstrated that this is a significant advancement in the realm of herbal nanoparticulated drug delivery and in setting the regulatory benchmarks for herbal products.

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ABBREVIATIONS

UV: Ultraviolet/visible Spectroscopy; **CNS:** Central Nervous System; **mg:** Miligram; **HPMC:** Hydroxypropyl Methylcellulose; **SPPU:** Savitribai Phule Pune University, Pune.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

SUMMARY

Medicated kajal was developed using *Areca catechu*, a valuable Ayurvedic plant known for treating fever, headaches, and rheumatism. Carbon filaments were made from cow ghee, Camphor, coconut, and nutmeg. Two formulations, kajal and an *in situ* gel, were developed using these carbon filaments and the extract of *Areca catechu*. The formulated products were assessed and standardized using analytical markers. Investigating this medicated kajal and *in situ* gels could further enhance its application in medicine.

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