ISSN 1998 – 409X

ORIGINAL ARTICLE

Comparative pharmaceutical standardization of *Nimba* (*Azadirachta indica* A. Juss) *Kshara* prepared from *Nimba Kashtha* (Trunk Wood) and *Nimba Kandatwak* (Trunk Bark)

Shubham Gadekar, Krushnkumar Taviad, Bharat Kalsariya

Upgraded Department of Rasashastra and Bhaishajya Kalpana, Government Ayurved College and Hospital, Vadodara, Gujarat, India

Abstract

Introduction: *Kshara Kalpana* is an alkaline, water-soluble Ayurvedic preparation known for its therapeutic efficacy in the management of various diseases, both internally and externally. Classical texts such as Rasa Tarangini mention *Nimba Kashtha* (NK) (trunk wood) for *Nimba Kshara* preparation; however, its harvesting may be environmentally undesirable. This study aimed to develop and validate a standard manufacturing procedure (SMP) for *Nimba Kshara* and compare NK and *Nimba Kandatwak* (trunk bark) with respect to pharmaceutical yield and process reproducibility. **Materials and Methods:** Fresh *Nimba Kashtha* and *Nimba Kandatwak* were collected following good agricultural and collection practices. Three batches of *Kshara* were prepared from each raw material using classical procedures, including ash preparation, *Ksharajala* extraction (1:4 w/v), 3-h sedimentation, triple-cloth filtration, and evaporation. Pharmaceutical parameters, yield, and batch-to-batch reproducibility were assessed to establish the SMP. **Results:** Both starting materials yielded uniform, grayish-white ash and clear, alkaline *Ksharajala* across all batches. *Nimba Kandatwak* produced a substantially higher total ash yield than NK (4.94% vs. 1.45%). Although NK showed higher ash-to-*Kshara* conversion efficiency (21.8% vs. 13.8%), the overall *Kshara* yield from the initial dry material was approximately 2 times higher for *Nimba Kandatwak* (0.68%) than for *Nimba Kashtha* (0.32%). The developed SMP demonstrated consistent processing parameters and reproducible product quality across all batches. **Conclusion:** The SMP provided reproducible processing conditions for *Nimba Kshara*. *Nimba Kandatwak* showed comparable processing characteristics to NK and yielded more *Kshara* per unit of dry raw material. These findings indicate its potential as an alternative raw material, subject to further validation and standardization.

Key words: Ayurveda, biomass, *Kalpana*, *Ksharajala*, pharmaceutical, standardization

INTRODUCTION

The escalating global demand for plant-derived therapeutics, nutraceuticals, and cosmetics necessitates stringent quality control and sustainable sourcing strategies.[1,2] Within this context, the valorization of underutilized plant biomass, particularly bark generated during forestry and timber processing, presents a crucial opportunity for sustainable resource management in traditional medicine systems.[3] Utilizing such biomass as a value-added pharmaceutical raw material can significantly minimize waste while preserving vital medicinal plant populations.

In Ayurvedic pharmaceutics, medicinal plants are processed into diverse dosage forms to enhance bioavailability and efficacy. Among these, *Kshara Kalpana* represents a highly specialized preparation comprising a concentrated,

Address for correspondence:
Dr. Shubham Gadekar, Upgraded Department of Rasashastra and Bhaishajya Kalpana, Government Ayurved College and Hospital, Vadodara, Gujarat, India.
Mobile: +91 7385194097.
E-mail: drshubhamgadekar@gmail.com

Received: 10-08-2026
Revised: 19-09-2026
Accepted: 29-09-2026

© 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0)

water-soluble alkaline extract derived from plant ash.[4] Classical literature documents the use of various botanical parts, including the whole plant,[5] roots,[6] fruit,[7] fruit rind,[8] leaves,[9] and bark[10] for *Kshara* extraction. For the preparation of *Nimba Kshara* (*Azadirachta indica* A. Juss.), authoritative texts such as Rasa Tarangini explicitly recommend the use of *Nimba Kashtha* (NK) (trunk wood).[11]

However, an exclusive reliance on trunk wood raises ecological concerns regarding the long-term sustainability of the plant resource. Utilizing *Nimba Kandatwak* (trunk bark) instead could provide a sustainable, high-yield alternative, facilitating the pharmaceutical valorization of bark biomass. Furthermore, the traditional preparation of *Kshara* involves multiple critical processing parameters such as raw-material incineration, water proportions, sedimentation time, and heat concentration. Unstandardized approaches to these steps frequently lead to significant batch-to-batch variations in both the yield and physicochemical quality of the final alkaline extract.

Currently, there is a lack of comparative pharmaceutico-analytical data assessing *Nimba Kshara* derived from wood versus bark. Therefore, the present study aims to comparatively evaluate the pharmaceutical profiles of *Nimba Kshara* prepared from *Nimba Kashtha* (trunk wood) and *Nimba Kandatwak* (trunk bark), and to establish a validated standard manufacturing procedure (SMP) to ensure consistent, quality-assured, and sustainable production.

MATERIALS AND METHODS

The pharmaceutical study was conducted in two systematic phases: first, botanical sourcing, pharmacognostic authentication, and primary processing of the crude plant materials, and second, pharmaceutical manufacturing and process standardization of *Nimba Kshara* evaluated across three batches.

Botanical Sourcing, Authentication, and Primary Processing

Fresh crude samples of NK (trunk wood comprising heartwood, sapwood, and attached bark) and *Nimba Kandatwak* (isolated outer and inner trunk bark) were harvested from authenticated, healthy *Azadirachta indica* A. Juss. (Family: Meliaceae) trees located at Dugaon, Chandwad, Nashik District, Maharashtra, India (coordinates: 20.329956° N, 74.243791° E; elevation: ~632 m above mean sea level) on March 31, 2025, during the pre-monsoon summer season. Sampling was strictly restricted to mature specimens (estimated age: 25–28 years) showing no visible evidence of fungal infestation, entomological damage, or physiological disease [Figure 1]. The collected botanical specimens were verified at the Pharmacognosy Laboratory, Department of Dravyaguna, Government Ayurved College, confirming identity and purity via macroscopic organoleptic profiling, cross-sectional anatomy, and powder microscopy in accordance with pharmacopoeial standards.[12]

A total of 68 kg of fresh NK and 61 kg of *Nimba Kandatwak* were harvested [Figure 2]. The raw materials were sized into uniform pieces (approximate dimensions: 8 × 5 cm), washed under running potable water to eliminate extraneous debris and siliceous matter, and subjected to open-air solar drying for 32 consecutive days. The dried weights stabilized at 48 kg (NK) and 46 kg (*Nimba Kandatwak*). To maintain uniform batch parameters and ensure statistical reproducibility, 45 kg of dried biomass from each botanical source was utilized to execute three independent, identical manufacturing batches (15 kg dry weight per batch) [Figure 2].

Pharmaceutical Formulation and SMP

Pharmaceutical processing was performed in the upgraded Department of Rasashastra and Bhaishajya Kalpana, Government Ayurved College, Vadodara, Gujarat, India. To develop an SMP, a minimum of three batches each of *Nimba Kshara* prepared from *Nimba Kashtha* and *Nimba Kandatwak* were manufactured. The preparation involved sequential steps, including controlled incineration (ash preparation), maceration and clarification (*Ksharajala* Extraction), and evaporation and product crystallization (*Kshara* Isolation), to obtain the respective *Kshara* according to the method described in Rasatarangiṇi for *Kṣhara* preparation.[11] Accordingly, *Nimba Kashtha* Ash (NKA), *Nimba Kashtha Ksharajala* (NKKJ), and *Nimba Kashtha Kshara* (NKK), as well as *Nimba Kandatwak* Ash (NKTA), *Nimba Kandatwak Ksharajala* (NKTKJ), and *Nimba Kandatwak Kshara* (NKTK), were prepared and evaluated during the study.

Preparation of NKK

Controlled incineration (ash formation)

The dried NK was then placed in an iron pan and ignited. Thereafter, pieces of NK were added sequentially at regular intervals of 15 min in the following quantities: 0.5 kg 3 times, 1 kg 5 times, 2 kg 3 times, and finally 2.5 kg once. The material was allowed to burn until ash formed. After self-cooling, the obtained ash was collected, weighed, and stored in an airtight container for further pharmaceutical processing [Figure 3].

Maceration and clarification (Ksharajala extraction)

The collected ash was transferred into a plastic beaker, and 4 times reverse osmosis (RO) water (v/v) was added to it. The mixture was thoroughly macerated to facilitate proper dissolution of the soluble contents and was kept undisturbed for 3 h. After the settling period, the clear supernatant liquid was carefully drained through a rubber tube without



Figure 1: Collection of *Nimba Kashtha* and *Nimba Kandatwak*

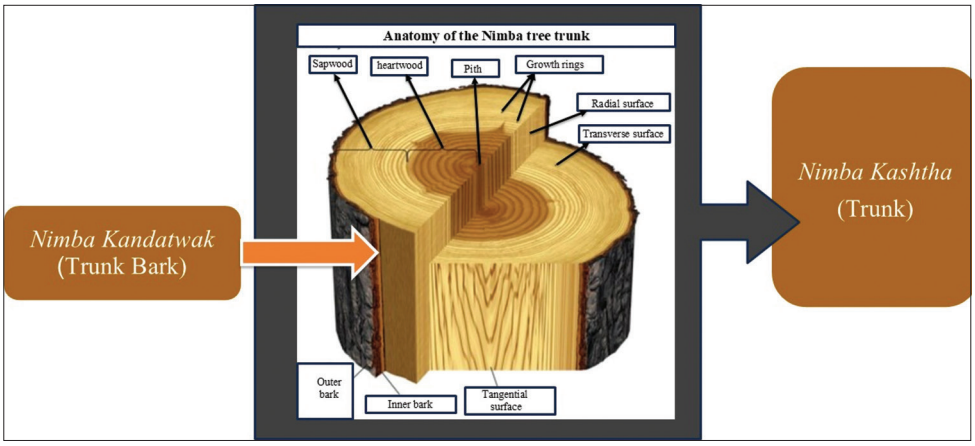


Figure 2: Specification of plant parts for collection



Figure 3: Preparation of *Nimba Kashtha* ash

disturbing the sediment. The drained liquid was then filtered through a three-folded cotton cloth to remove suspended impurities. The filtrate thus obtained was collected as NK *Ksharajala* [Figure 4].

Evaporation and product crystallization (Kshara isolation)

The clarified NKKJ filtrate was transferred to a stainless steel (SS-316) vessel and subjected to regulated thermal evaporation over a controlled gas burner. The boiling solution was stirred continuously as evaporation progressed toward a concentrated, viscous paste. Thermal energy was attenuated during the terminal phase to prevent charring or localized salt degradation. Upon complete dehydration, off-white, crystalline NKK was recovered, ground in a porcelain mortar to pass through a standard #60 mesh sieve, and sealed in airtight borosilicate glass jars [Figure 5].

Preparation of *Nimba Kshara* from *Nimba Kandatwak* (NKTK)

A similar method involving controlled incineration (ash preparation), maceration and clarification (*Ksharajala* Extraction), and finally evaporation and product crystallization (*Kshara* isolation) was followed for the preparation of *Nimba Kandatwak Kshara* [Figures 6-8].

OBSERVATION AND RESULTS

Observations and Results of NKK

Controlled incineration (ash formation)

Details of observations and results are presented in Tables 1 and 2.

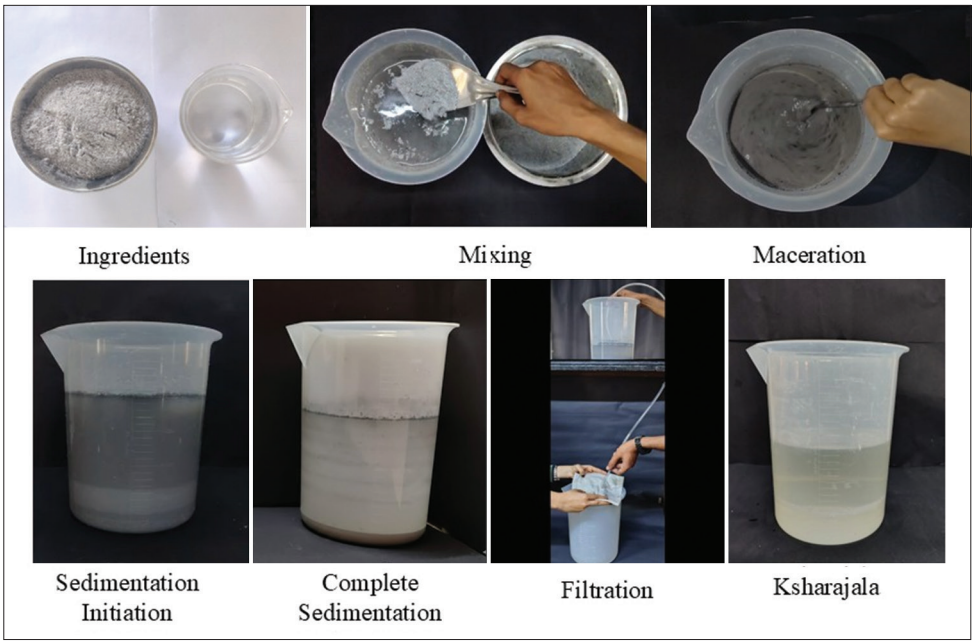


Figure 4: Preparation of *Nimba Kashtha Ksharajala*

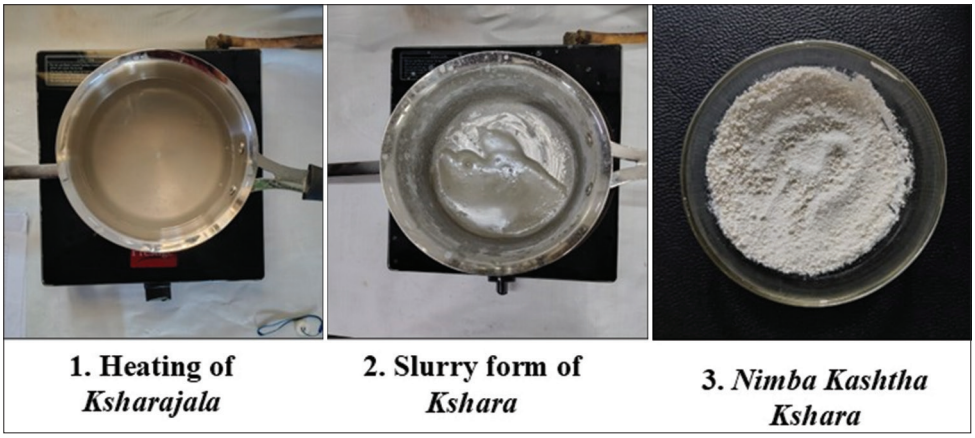


Figure 5: Preparation of *Nimba Kashtha Kshara*



Figure 6: Preparation of *Nimba Kandatwak* ash

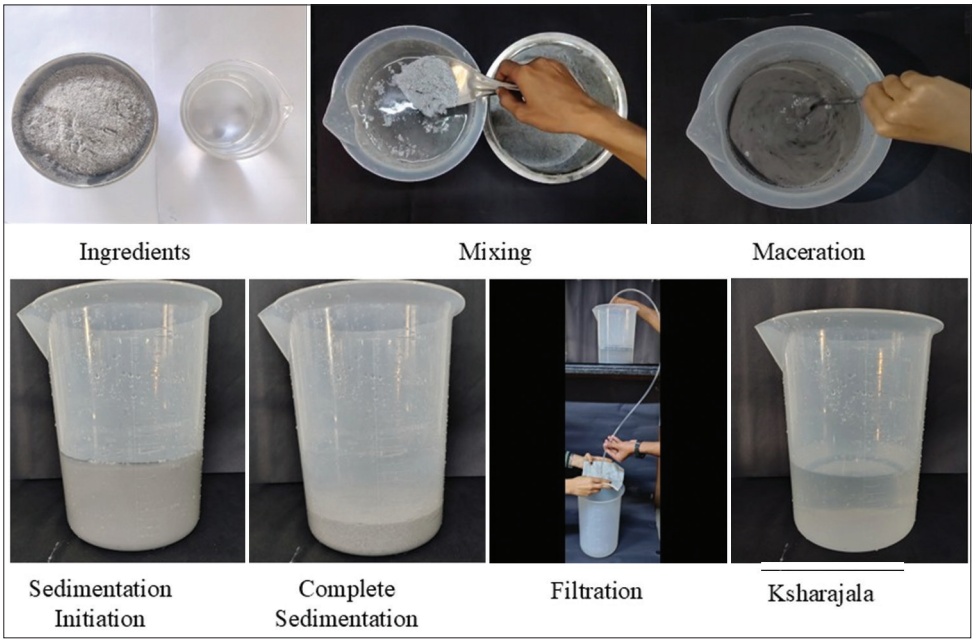


Figure 7: Preparation of *Nimba Kandatwak Ksharajala*

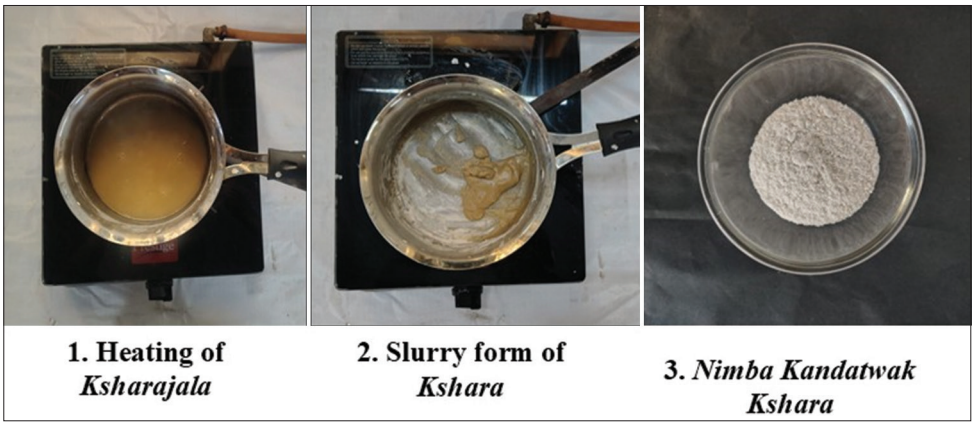


Figure 8: Preparation of *Nimba Kandatwak Kshara*

Table 1: Details of observations during preparation of *Nimba Kashtha* Ash

Time (h: min)	Quantity of *Nimba Kashtha* added to the iron pan (kg)			Observations
	Batch-1	Batch-2	Batch-3	
00:00	0.502	0.512	0.500	*Nimba Kashtha* was added to the iron pan. The material took time to ignite and produced white fumes
00:15	0.510	0.500	0.511	
00:30	0.508	0.520	0.500	White fumes disappeared, and the *Kashtha* burned with a yellow flame
00:45	1.020	1.018	1.002	
01:00	1.020	1.028	1.006	Burnt material had settled at the bottom of the iron pan
01:15	1.020	1.010	1.005	
01:30	1.012	1.020	1.012	
01:45	1.018	1.000	1.013	
02:00	2.010	2.020	2.000	
02:15	2.015	2.018	2.004	
02:30	2.004	2.004	2.007	Flames from the burning material emerged from the iron pan
02:45	2.500	2.504	2.502	
03:00	-	-	-	The flames disappeared
03:15	-	-	-	The iron pan was filled with glowing embers
Allow to self-cooling				
14:30	-	-	-	Grayish-white ash was obtained.

Table 2: Results obtained during the preparation of *Nimba Kashtha* Ash

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Quantity of *Nimba Kashtha* after drying				
kg	15	15	15	15
Final quantity of Ash obtained from dried *Nimba Kashtha*				
g	239	205	210	218
%	1.59	1.36	1.4	1.45
Total loss in ash preparation				
kg	14.76	14.79	14.79	14.78
%	98.4	98.6	93.3	96.7
Total time taken for preparation of *Nimba Kashtha* ash				
(h: Min)	14:30 (03:15: Burning 11:15: Self-cooling)	14:30 (03:15: Burning 11:15: Self-cooling)	15:00 (03:15: Burning 11:45: Self-cooling)	14:53
Reason for loss in ash preparation	Due to the burning of the organic part of the material			

Maceration and Clarification (*Ksharajala* Extraction)

Observations

Immediate effervescence was observed upon the addition of water to the ash. After 30 min, most of the ash particles had settled at the bottom of the vessel, whereas a few particles remained floating on the surface of the liquid. Following 3 h of sedimentation, the decanted liquid (*Ksharajala*) appeared transparent and light yellow in color. Organoleptic evaluation revealed that the obtained *Ksharajala* possessed a salty taste. Details of the results are presented in Table 3.

Evaporation and Product Crystallization (*Kshara* Isolation)

Details of the temperature pattern and results are presented in Graph 1 and Table 4.

Table 3: Results obtained during preparation of *Nimba Kashtha Ksharajala*

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Total quantity of ash				
mL	500	500	500	500
g	239	205	210	218
Total quantity of water				
mL	2000	2000	2000	2000
g	1860	1860	1860	1860
Total quantity of *Ksharajala* obtained after decantation and filtration				
mL	1250	1310	1270	1276.6
g	1158	1217	1172	1195.6
% of *Ksharajala* obtained				
v/v	62.5	65.5	63.5	63.8
w/w	62.2	65.4	63	63.5
Total loss				
mL	750	690	730	723.3
g	702	643	688	677.6
% of loss of *Ksharajala*				
v/v	37.5	34.5	36.5	36.1
w/w	37.7	34.5	36.9	36.3
Time taken for preparation of *Nimba Kashtha Ksharajala* (h: Min)	3:45	3:55	3:50	3:50
Reason for loss	Due to decantation and filtration			

Observations and Results of *Nimba Kandatwak Kshara*

Controlled incineration (ash formation)

Details of observations and results are presented in Tables 5 and 6.

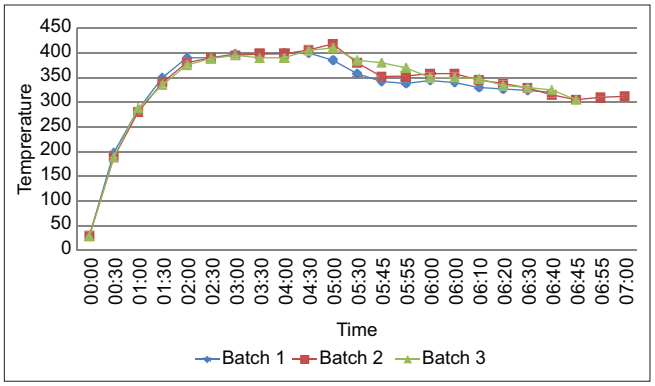
Maceration and Clarification (*Ksharajala* Extraction)

Observations

Immediate effervescence was observed upon the addition of water to the ash. After 30 min, most of the ash particles had settled at the bottom of the vessel, whereas a few particles remained floating on the surface of the liquid. Following 3 h of sedimentation, the decanted liquid (*Ksharajala*) appeared transparent and light yellow in color. Organoleptic evaluation revealed that the obtained *Ksharajala* possessed a salty taste. Details of results are presented in Table 7.

Evaporation and Product Crystallization (*Kshara* isolation)

Details of the temperature pattern and results are presented in Graph 2 and Table 8.



Graph 1: Temperature at different intervals during preparation of *Nimba Kashtha Kshara*

DISCUSSION

Bark biomass is generated in substantial quantities as an industrial by-product of timber and forestry processing; it is frequently discarded as waste, presenting persistent environmental and disposal challenges.[3] Repurposing this botanical biomass for *Kshara* synthesis directly aligns with the principles of green extraction and sustainable bio-resource valorization. Botanically, NK (trunk wood) and *Nimba Kandatwak* (trunk bark) both originate from the

Table 4: Results obtained during the preparation of *Nimba Kashtha Kshara*

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Total quantity of *Ksharajala*				
mL	1250	1310	1270	1276.6
g	1158	1217	1172	1182.3
Quantity of *Kshara* obtained				
g	46	50	47	47.6
Percentage of *Kshara* (%)				
Compared to *Ksharajala* (v/w)	3.68	4	3.76	3.81
Compared to ash				
(w/w)	19.24	24.39	22.38	22
(v/w)	9.2	10	9.4	9.6
Compared to dry plant (w/w)	0.3	0.3	0.3	0.3
Time taken for evaporation of *Ksharajala* (h: Min)	06:40	07:00	06:45	06:48
Reason for loss	Due to evaporation of water			

Table 5: Details of observations during preparation of *Nimba Kandatwak* ash

Time (h: Min)	Quantity of *Nimba Kandatwak* added to iron pan (kg)			Observations
	Batch-1	Batch-2	Batch-3	
00:00	0.500	0.502	0.500	It burned easily and produced white fumes with the mild crackling sound.
00:15	0.502	0.500	0.502	White fumes disappeared, and the *Kandatwak* burned with a yellow flame.
00:30	0.506	0.504	0.500	
00:45	1.002	1.000	1.002	
01:00	1.004	1.006	1.006	Burnt material had settled at the bottom of the iron pan.
01:15	1.002	1.002	1.004	
01:30	1.000	1.002	1.006	
01:45	1.000	1.000	1.004	
02:00	2.010	2.002	2.000	
02:15	2.004	2.006	2.004	
02:30	2.004	2.002	2.004	Flames from the burning material emerged from the iron pan.
02:45	2.500	2.500	2.502	
03:00	-	-	-	The flame disappeared.
03:15	-	-	-	The iron pan was filled with glowing embers.
Allow to self-cooling				
14:30	-	-	-	Grayish-white ash was obtained.

vascular cambium during secondary growth and concentrate distinct inorganic mineral fractions and residual secondary metabolites, providing a clear biological and pharmaceutical rationale for their comparative evaluation[3] Although *Nimba Kshara* possesses established therapeutic efficacy in anorectal disorders and chronic wound management – specifically in conditions such as *Bhagandara* (fistula-in-ano),[13] *Arsha* (hemorrhoids),[14] *Dushta Vrana* (chronic ulcers),[15] *Nadivrana* (pilonidal sinus/sinus tracts), *Parikartika* (fissure-in-ano),[16] and *Karnini Yonivyapada* (cervical erosion)[17] extant literature has concentrated predominantly on clinical efficacy. To date, no systematic investigation has evaluated the comparative pharmaceutical standardization of *Kshara* derived from disparate anatomical parts of *Azadirachta indica*, nor does the Ayurvedic Pharmacopeia of India stipulate a standardized manufacturing monograph for *Nimba*

Table 6: Results of process validation of *Nimba Kandatwak* ash

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Quantity of *Nimba Kandatwak* after drying				
kg	15	15	15	15
Final quantity of Ash obtained from dried *Nimba Kandatwak*				
g	748	720	758	742
%	4.98	4.8	5.05	4.94
Total loss in ash preparation				
kg	14.252	14.280	14.258	14.354
%	96.8	95.2	95	95.66
Total time taken for the preparation of *Nimba Kandatwak* ash				
(h: Min)	14:30 (03:15: Burning 11:15: Self-cooling)	14:30 (03:15: Burning 11:15: Self-cooling)	14:30 (03:15: Burning 11:15: Self-cooling)	14:30
Reason for loss in ash preparation	Due to the burning of the organic part of the material			

Table 7: Results obtained during preparation of *Nimba Kandatwak Ksharajala*

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Total quantity of ash				
mL	500	500	500	500
g	193	188	205	195.3
Total quantity of water				
mL	2000	2000	2000	2000
g	1860	1860	1860	1860
Total quantity of *Ksharajala* obtained after decantation and filtration				
mL	1350	1280	1250	1293.33
g	1267	1178	1156	1200.33
% of *Ksharajala* obtained				
v/v	67.5	64	62.5	64.66
w/w	68.11	63.33	62.15	64.53
Total loss				
mL	650	720	750	706.66
g	593	682	704	659.66
% of loss of *Ksharajala*				
v/v	32.5	36	37.5	35.33
w/w	31.88	36.66	37.84	35.46
Times taken for preparation of *Nimba Kandatwak Ksharajala* (h: min)	4:00	3:45	3:35	3:46
Reason for loss	Due to decantation and filtration			

Kshara. The present study addresses this knowledge gap by establishing a validated SMP and elucidating the operational dynamics of raw biomass conversion into standardized alkaline isolates.

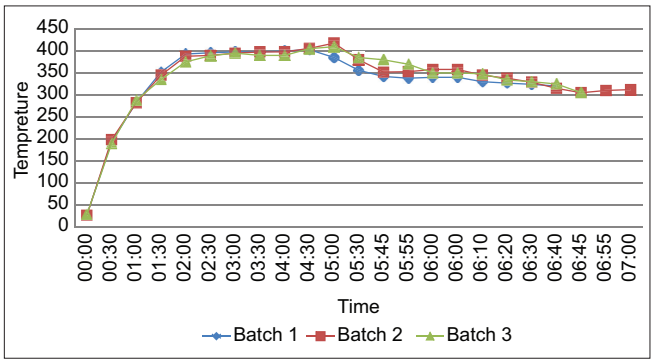
Discussion on Collection

Harvesting of crude NK and *Nimba Kandatwak* was executed in March 2025 in strict compliance with World

Health Organization and National Medicinal Plants Board good agricultural and collection practices guidelines. The late-winter to early-summer transitional period coincides with heightened metabolic activity in deciduous and semi-evergreen arboreal species while offering optimal ambient temperatures and low relative humidity. These environmental conditions accelerated solar dehydration, inhibited post-harvest microbial proliferation, and prevented hydrolytic deterioration of the biomass, ensuring high starting material integrity and batch uniformity prior to thermal processing.

Discussion on Controlled Incineration (ash Formation)

The controlled combustion of botanical biomass was executed in an unconfined open environment to maintain continuous atmospheric oxygen availability (O_2), facilitating complete oxidative degradation of organic biopolymers (cellulose, hemicellulose, and lignin) into gaseous carbon dioxide (CO_2) and water vapor (H_2O), while selectively concentrating non-volatile inorganic minerals.[18] The incremental, staged addition of dried biomass at 15-min intervals served as a critical in-process control parameter. This controlled feeding regimen prevented thermal quenching, avoided localized overheating that could volatilize low-melting alkali salts, and maintained uniform combustion thermodynamics. The progression of combustion – from transient initial white fumes representing moisture vaporization and loss of volatile organic fractions to steady incandescent yellow flames-indicated efficient pyrolysis of lignocellulosic matrices.[18,19] The resulting grayish-white coloration of both ashes served as a visual endpoint for complete mineralization, whereas incomplete combustion, characterized by residual black carbonaceous char, impedes downstream solid-liquid mass transfer and diminishes final alkaline recovery. Notably, *Nimba Kandatwak* yielded substantially higher crude ash than NK (4.94% vs. 1.45%), which is attributable to the anatomical concentration of structural calcium, oxalates, and mineral deposition in outer secondary phloem and cortical tissues, whereas the heartwood/sapwood core contains higher combustible organic structural polymers that volatilize during incineration. Despite this threefold difference in ash yield, processing durations remained virtually identical, demonstrating comparable operational feasibility.



Graph 2: Temperature at different intervals during preparation of *Nimba Kandatwak Kshara*

Discussion on Maceration and Clarification (*Ksharajala* Extraction)

The extraction of alkaline salts was standardized using RO-purified water rather than potable water to eliminate exogenous interference from dissolved minerals.[20] RO water prevents the introduction of extraneous calcium, magnesium, carbonates, and heavy mineral ions typically present in tap water, ensuring that the finished product's ionic profile reflects purely the botanical source. The ash-to-solvent ratio

Table 8: Results obtained during the preparation of *Nimba Kandatwak Kshara*

Parameters	Result			
	Batch 1	Batch 2	Batch 3	Average
Total quantity of *Ksharajala*				
mL	1350	1280	1250	1293.33
g	1267	1178	1156	1200.33
Quantity of *Kshara* obtained				
g	22	28	32	27.33
Percentage of *Kshara* (%)				
Compared to *Ksharajala* (v/w)	1.73	2.37	2.76	2.28
Compared to ash				
(w/w)	11.39	14.89	15.6	13.96
(v/w)	4.4	5.6	6.4	5.4
Compared to dry plant (w/w)	0.14	0.18	0.21	0.17
Time taken for evaporation of *Ksharajala* (h: Min)	06:40	07:00	06:45	06:48
Reason for loss	Due to the evaporation of water			

directly governs mass transfer kinetics during extraction; an insufficient volume of solvent causes incomplete salt dissolution due to phase saturation, whereas excessive dilution exponentially increases the thermal energy and operational time required for concentration without enhancing extraction yields. Classical Ayurvedic treatises document diverse solvent ratios ranging from 1:4 to 1:16, including 1:4 as prescribed by AstangaSangraha,[21] AstangaHridaya,[22] VangasenaSamhita, SharangadharaSamhita,[23] Rasapradipa, AyurvedaPrakasha,[24] and RasaTarangini[11]; 1:6 as recommended by SushrutaSamhita,[25] Chakradatta,[26] and DravyagunaVijnana; and higher dilutions such as 1:8 in Ayurveda Sara Sangraha[21] or 1:16 in Rasajalanidhi. The selection of a 1:4 (w/v) ratio in the present investigation, as delineated in Rasa Tarangini, achieved optimal dissolution of water-soluble alkaline salts while containing evaporative volume, thereby maximizing process efficiency and operational throughput. The 3-h static gravitational sedimentation period, preceded by thorough manual maceration, provided the contact time necessary for inorganic salt dissolution while permitting dense, water-insoluble siliceous and metallic particulates to form a settled bed, enabling clean supernatant siphoning prior to triple-cloth filtration.

Discussion on Evaporation and Product Crystallization (*Kshara* isolation)

Evaporation of clarified *Ksharajala* over sustained heat culminated in the precipitation of a pristine, white crystalline solid, confirming the effective elimination of suspended carbonaceous impurities during filtration. The white crystalline habit is characteristic of crystallized alkali metal carbonates, sulfates, and chlorides. A detailed mass-balance comparison revealed critical pharmaceutical trade-offs between the two starting materials. When evaluated strictly per unit weight of ash, NK *Ash* (NKA) exhibited a higher conversion rate into soluble *Kshara* (21.8%; 47.6 g from standardized *Ksharajala*) compared to NKTA (13.8%; mean 27.33 g), confirming that wood ash contains a higher relative proportion of water-soluble alkaline salts, whereas bark ash possesses a greater fraction of water-insoluble mineral oxides and siliceous residue. However, when assessed against initial dry biomass (15 kg), *Nimba Kandatwak* demonstrated a twofold higher overall formulation yield (0.68%; mean 102.4 g) relative to NK (0.32%; mean 47.6 g) [Figure 9].

This elevated net output demonstrates that the greater total ash yield of bark biomass (4.94%) more than offsets its

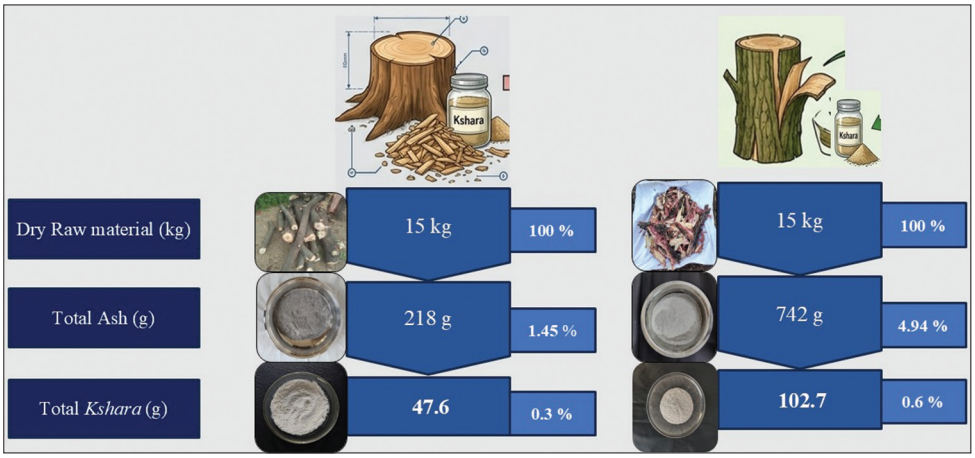


Figure 9: Comparative yield of *Nimba Kashtha Kshara* and *Nimba Kandatwak Kshara*

Sr. No.	Parameter	*Nimba Kashtha*	*Nimba Kandatwak*	Remarks
1.	**Yield** (Compared to dry material)	⊗	✓	***Kandatwak* offers higher yield** per unit of dry raw material, making extraction significantly more efficient than Kashtha.
2.	**Cost**	⊗	✓	***Kandatwak* is more cost-effective** due to lower harvesting/procurement overheads compared to whole wood logging.
3.	**Ease of processing**	⊗	✓	***Kandatwak* is significantly easier to pulverize and extract**, whereas fibrous, hard wood (Kashtha) causes higher equipment wear and longer cycle times.
4.	**Sustainability**	⊗	✓	***Kandatwak* allows sustainable harvesting** through regulated bark collection without felling the tree, unlike *Kashtha* which requires destructive harvesting.

Figure 10: Comparative yield of *Nimba Kashtha Kshara* and *Nimba Kandatwak Kshara*

lower water-soluble extractive fraction. Consequently, *Nimba Kandatwak* provides superior raw-material utilization efficiency, reduced manufacturing costs, and greater alignment with ecological conservation objectives compared to NK [Figure 10].

While this study successfully establishes an operational SMP and confirms the pharmaceutical feasibility of utilizing *Nimba Kandatwak*, several considerations warrant future research. The present investigation was conducted on a single seasonal batch harvested from a defined geographical location. Multiseasonal and multiregional sampling, coupled with advanced chemometric characterization including Inductively Coupled Plasma Mass Spectrometry for elemental profiling, PXRD for crystalline phase identification, and attenuated total reflectance Fourier-transform infrared spectroscopy, is recommended to reinforce regulatory monographs. Furthermore, comparative *in vitro* antimicrobial assays and randomized clinical evaluations are warranted to validate pharmacological bioequivalence between wood- and bark-derived *Nimba Kshara*.

CONCLUSION

The present study successfully established and validated a reproducible SMP for *Nimba Kshara*, optimizing critical unit operations across triplicate batches. Although NK showed higher ash-to-*Kshara* conversion efficiency (21.8% vs. 13.8%), the overall *Kshara* yield from the initial dry material was approximately 2 times higher for *Nimba Kandatwak* (0.68%) than for *Nimba Kashtha* (0.32%). Consequently, valorizing renewable trunk bark biomass presents an economically viable, high-yield, and eco-sustainable alternative to destructively harvesting trunk wood, providing a robust pharmaceutical standardization model for commercial Ayurvedic manufacturing and pharmacopoeial monographs.

REFERENCES

1. World Health Organization. WHO Global Centre for Traditional Medicine (GCTM), India: Strategic Overview. Geneva: World Health Organization; 2022. Available from: https://www.who.int/publications/m/item/who-global-centre-for-traditional-medicine-(gctm)-india [Last accessed on 2026 Aug 07].
2. Muyumba NW, Mutombo SC, Sheridan H, Nachtergael A, Duez P. Quality control of herbal drugs and preparations: The methods of analysis, their relevance and applications. Talanta Open 2021;4:100070.
3. Supriyadi D, Damayanti D, Veigel S, Hansmann C, Gindl-Altmutter W. Unlocking the potential of tree bark: Review of approaches from extractives to materials for higher-added value products. Mater Today Sustain 2025;29:101074.
4. Jadav HR, Galib R, Prajapati PK. Pharmaceutical standardization of Apamarga Kshara. J Ayurveda Integr Med 2015;6:290-94.
5. Sushruta A, Samhita S, editor. Shastri Ambikadatta, Ver. 11-14, Sutra Sthana Ch. 11. Varanasi: Chaukhambha Sanskrita Samsthana; 2017. p. 46.
6. Savaliya V, Kumar V, Nariya M, Prajapati P, Shukla V. Pharmaceutical standardization of MulakaKshara: An ayurvedic preparation. World J Pharm Res 2016;5:1040-51.
7. Kupati VB, Athavale PM. Pharmaceutico-analytical study of VidangadiKshara with special reference to its anticancer activity. Int J Biol Pharm Allied Sci 2025;14:4783-93.
8. Pandya NR, Vyas K, Kalsariya B. A Comparative Pharmaceutico-Analytical Study of ChinchaKshara Prepared from Different Parts of Chincha (*Tamarindus indica* Linn.). Ayu, MD [Dissertation]; 2023.
9. Acharya S, Panda PK, Acharya G, Mohanty N, Nathsharma PK, Dash SC. A comparative clinical trial of Chincha kshara and Kadali kshara on Amlapitta. AYU 2011;32:494-9.
10. Sapna S, Pachori M, Mohanan M. A clinical study to examine the impact of Eranda Patra Kshara on Sthaulya (obesity). J Ayurvedic Herb Med 2023;9:114-8.
11. Sharma S. Rasa Tarangini by Sadananda Sharma edited by Kashinath Shastri P. 11th ed., Ver 59-61., Ch. 14. Delhi: Motilal Banarasidass; 2012. p. 338.
12. Gadekar S, Jani D, Taviad K, Kalsariya B. Comparative pharmacognostic evaluation of trunk bark and trunk wood of Nimba (*Azadirachta indica* A. Juss.). J Pharmacogn Phytochem 2026;15:501-10.
13. Rai PP, Gupta S. Evaluation of Guggulu Nimba Ksharasutra Ligation with Saptanga Guggulu orally in Bhagandara (Fistula-in-Ano). Hardwar, Uttaranchal: Department of Shalya Tantra, Patanjali Ayurveda Hospital; 2023.
14. Lawate US, Gajare K. Randomized Controlled Trial of Nimba Kshara Pratisarana in the Management of Abhyantara Arsha (Internal Haemorrhoids) with Compare to Standard Apamarga Kshara. Pune: Department of Shalyatantra, MAMs Sumatibhai Shah Ayurved Mahavidyalaya and Hospital; 2025.
15. Dhawane MS, Shedge A. Randomised Controlled Clinical Study to Evaluate the Efficacy of Nimba Pratisarniya Kshara Application in the Management of Dushta Vrana with Special Reference to Infected Wound. Islampur: Department of Shalyatantra, LRP Ayurvedic Medical College and Hospital; 2024.
16. Thorat MN, Gundre R. Randomized Controlled Clinical Study to Evaluate the Efficacy of Nimba Kshara Taila in the Management of Nadi Vrana (Pilonidal Sinus). Aurangabad: Department of Shalya Tantra, C.S.M.S.S Ayurved Mahavidyalaya and Rugnalaya; 2024.
17. Pruthvi C, Madhu M. Clinical Study on the Combined Effect of Nimba Kshara, Aragwdha Kashaya Yoni Prakshalana and Aragwadhadi Taila Yoni Pichu in the Management of Karnini Yonivyapada (Cervical Erosion).

Hassan: Department of Prasuti Tantra and StreeRoga, Sri Dharmasthala Manjunatheshwara College of Ayurveda and Hospital; 2025.
18. Emmons HW, Atreya A. The science of wood combustion. Proc Indian Acad Sci (Eng Sci) 1982;5:259-68.
19. Barma MC, Saidur R, Rahman SM, Allouhi A, Akash BA, Sait SM. A review on boilers energy use, energy savings, and emissions reductions. Renew Sustain Ener Rev 2017;79:970-83.
20. Tayeh YA. A comprehensive review of reverse osmosis desalination: Technology, water sources, membrane processes, fouling, and cleaning. Desalinat Water Treat 2024;320:100882.
21. Baidyanatha. Anonymous, Ayurveda Sara Sangraha. Alhabada: Shri Vaidhyanatha Ayurveda Bhawana Limited.; 2021. p. 697.
22. Vagbhatta AS. Ashtanga Hridaya, edited by Bramhmanand Tripathi. Ver. 8-21., Sutrasthana Ch. 30. Varanasi, Delhi: Chaukhambha Sanskrit Prakashan; 2017. p. 329.
23. Sharangadhara A. Sharangadhara Samhita, edited by Dr. Bhramananda Tripathi, Madhyama Khanda. Ver. 102., Ch. 11. Varanasi: Chaukhambha Surabharati Prakashana; 2017. p. 185.
24. Upadhyaya AM. Ayurveda Prakasha, Commentary by Mishra SG. Ver. 123., Ch. 6. Varanasi: Chaukhambha Bharati Academy; 2007. p. 503.
25. Vagbhatta AS. Ashtanga Samgraha, edited by Kaviraja Atrideva Gupt. Ver. 10-11., Sutrasthana, Ch. 39. Varanasi: Chaukhambha Sanskrita Prakashana; 2019. p. 255.
26. Chakrapanidatta A. Chakradatta, with Vaidyaprabha Hindi Commentary by Dr. Indradeva Tripathi, edited by Prof. Ramanath Dwivedi. Ch. 5., Ver. 138-147. Varanasi: Chaukhambha Sanskrit Bhavana; 2019. p. 65-6.

Source of Support: Nil. **Conflicts of Interest:** None declared.