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RESEARCH ARTICLE

Efficacy of Activated Charcoal Prepared from *Livistona chinensis* Seeds for Water Purification

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Abstract

This study explores the efficacy of activated charcoal derived from *Livistona chinensis* (Chinese fan palm) seeds for water purification. Activated charcoal was produced through chemical carbonization using concentrated sulphuric acid and neutralized with sodium bicarbonate solution. Fourier Transform Infrared Spectroscopy (FTIR) revealed significant structural changes in the charcoal, indicating enhanced adsorption sites. The practical efficacy of the activated charcoal was evaluated by treating it with two water samples, underground water (S_1, Patan, Lalitpur) and surface water (S_2, Ranipokhari, Kathmandu). Comprehensive water quality analysis (pH, conductivity, total dissolved solid (TDS), total hardness (TH), chloride, dissolved oxygen, heavy metals (Fe, Mn, Ni, Zn, Cd, Pb) was performed before and after treatment using standard methods and compared against WHO/NDWQS standards, and assessing changes in these parameters. Results demonstrated that the activated charcoal significantly reduced electrical conductivity and TDS, eliminated TH, and lowered chloride levels by 70–75% in both samples. It also effectively reduces concentrations of heavy metals such as iron, manganese, nickel, and cadmium as determined by Atomic Absorption Spectrophotometer (AAS). These findings underscore the potential of *Livistona chinensis* seeds as a cost-effective and sustainable raw material for the production of high-capacity activated charcoal, providing a viable strategy for enhancing water quality, especially in rural and resource-limited areas.

Keywords: *AAS, Activated charcoal, FTIR, Livistona chinensis, Water purification*

Introduction

Water is a vital resource for human existence and general well-being [1]. However, human endeavors like urbanization, industrialization, and agricultural runoff, introduce harmful contaminants into aquatic systems, and posing a growing threat to its quality. Among these pollutants, heavy metals are especially dangerous since they are hazardous and non-biodegradable, endangering aquatic ecosystems and human health [2]. For instance, Koju et al. (2022) reported elevated levels of heavy metals in industrial effluents from Kathmandu Valley, exceeding permissible limits and threatening surface and groundwater sources [3]. Similarly, a recent study by Hamal et al. (2025) revealed elevated arsenic concentrations in groundwater from Bedkot Municipality, Nepal, posing significant carcinogenic and non-carcinogenic risks, especially to children. These findings underscore the urgent need for effective, affordable, and locally accessible water purification technologies [4]. The World Health Organization (WHO) estimates that 80% of

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illnesses worldwide are caused by poor water quality and inadequate sanitation, showing how important it is to solve this problem [5, 6]. Although methods such as filtration, distillation, flocculation, and deionization are commonly used for water purification, they often present challenges and limitations [7, 8, 9]. The use of activated carbon in water purification systems has attracted considerable interest in recent years because of its effectiveness in eliminating a variety of contaminants [1].Activated carbon, also known as activated charcoal (AC), is a carbon-rich, highly porous material commonly used in water purification due to its large surface area, which allows it to adsorb a wide range of contaminants [2,10]. Numerous studies have explored the use of agricultural waste for producing AC as a sustainable and cost-effective alternative for water treatment. For example, Hussain et al. (2023) developed activated carbon from agricultural wastes such as banana peels, orange peels, pomegranate peels, and date stones for the removal of chlorpyrifos from water, achieving up to 98% removal efficiency with pomegranate peel-derived carbon [11]. Ahmed et al. (2022) prepared activated charcoal from walnut shells to purify water, and Shrestha (2015) investigated the adsorptive removal of Cd (II) ions using activated carbons derived from Lapsi seed stone [12, 13]. Similarly, Lakshmikandhan and Ramadevi (2019) prepared bicarbonate-treated *Acacia catechu* carbon (BTACC) from *Acacia catechu* seeds to remove lead from water [14]. In addition to water purification, it is used for decolorizing food and medication items, reducing air pollution, and cleaning chemicals [15]. Although AC has historically been made from wood and coconut shells, it is now increasingly made from a variety of lignocellulosic materials, including fruit pits and olive stones, which provide more affordable and environmentally friendly options [16]. Furthermore, almost any low-cost, carbon-rich material can serve as a precursor for AC synthesis [17, 18].

The production of AC involves carbonization followed by activation [2]. Activation can be achieved through physical or chemical methods, with the latter being preferred due to its effectiveness in developing a large surface area and highly porous structure at lower temperatures and shorter processing times [2,19]. It improves water quality by effectively removing contaminants such as pesticides, heavy metals, and chlorine residues, along with taste, color, and odor [1, 9]. It has been shown to reduce iron (Fe) levels from 12.60 mg/L to nearly 0 mg/L and nitrate (NO_3^-) levels from 23.90 mg/L to 0 mg/L, and it effectively removes sulphate (SO_4^{2-}), manganese (Mn), and chloride (Cl^-) [20,21]. Despite its effectiveness, commercial production remains costly due to reliance on non-renewable raw materials and complex manufacturing processes [16, 19]. *Livistona chinensis*, or the Chinese fan palm, is a commonly grown ornamental plant in subtropical regions [22]. Its olive-shaped fruits, often discarded as waste, contain seeds that could serve as a viable raw material for AC production. The potential of biochar derived from *Livistona chinensis* fruits for the adsorption of malachite green dye was previously investigated by Giri et al. in 2021 [22].However, despite the availability and potential of these seeds, the preparation and use of AC from them for water purification have yet to be studied.

With the objective to address this gap, the current study examines the production and effectiveness of activated charcoal made from *Livistona chinensis* seeds as an affordable and sustainable substitute for conventional activated charcoal. The study assesses the charcoal's capacity to eliminate impurities from water, offering valuable information on its potential to enhance water quality and encourage the use of sustainable agricultural waste materials for water treatment. Water quality assessment is essential for identifying

contamination levels and guiding appropriate treatment strategies. Standard references such as Standard Methods for the Examination of Water and Wastewater (APHA, 2023) and the Official Methods of Analysis (AOAC International, 2023) serve as authoritative resources for understanding fundamental and comprehensive methodologies used in the analysis of various physicochemical parameters of water [23,24].

Materials and Methods

Sample Collection

Livistona chinensis fruits were harvested from the garden of Tri-Chandra Multiple Campus, Ghantaghar, Kathmandu. Only ripe and undamaged fruits were selected, and they were placed in clean polyethylene bags for transport to the laboratory. The fruits were kept at room temperature until further use.

Additionally, water samples were collected during the pre mansoon using grab sampling method from multiple locations, including underground water from Patan, Lalitpur (S_1), and surface water from Ranipokhari, Kathmandu (S_2). The samples were collected in plastic bottles, which were rinsed three times with the distilled water and respective water source prior to sampling to avoid contamination, and stored at room temperature.

Chemicals

All analytical-grade chemicals were used in the experimental procedures without further purification. Concentrated sulphuric acid (H_2SO_4), buffer tablets (pH-4 and pH-7), potassium chloride (KCl), ammonia (NH_3), ammonium chloride (NH_4Cl), sodium hydroxide (NaOH), silver nitrate ($AgNO_3$), sodium azide (NaN_3), sodium chloride (NaCl), potassium dichromate ($K_2Cr_2O_7$), and starch were obtained from Thermo Fisher Scientific India Pvt. Ltd. Sodium bicarbonate ($NaHCO_3$) and manganese sulphate monohydrate ($MnSO_4{\cdot}H_2O$) were supplied by HiMedia Laboratories Pvt. Ltd. Eriochrome Black T (EBT) indicator and 85% phosphoric acid were sourced from Merck Specialities Pvt. Ltd., while ethanol was procured from Changshu Hongsheng Fine Chemical Co. Ltd. Potassium chromate (K_2CrO_4) was obtained from SD Fine Chem Ltd. Additional chemicals, including potassium iodide (KI), ethylenediaminetetraacetic acid (EDTA), sodium thiosulphate pentahydrate ($Na_2S_2O_3{\cdot}5H_2O$), and sodium carbonate (Na_2CO_3), were supplied by Merck Life Science Pvt. Ltd. Concentrated hydrochloric acid (HCl) was procured from Central Drug House (P) Ltd. Ultra super reagent grade triple deionized water was sourced from Mareech Pvt. Ltd. Lalitpur, Nepal.

Preparation of Precursor

Activated charcoal was synthesized using the seeds of *Livistona chinensis* fruits. Initially, the edible portions of the fruits were removed, and the seeds were thoroughly washed with deionized water to eliminate any surface contaminants. The cleaned seeds were sun-dried for one week and then subjected to hot air oven (PANACEA 430, Italy) drying at 110 °C for 24 hours to remove residual moisture. The dried seeds were crushed using a mortar and pestle, followed by grinding with an electric grinder (Philips HL7770/00, India) to achieve a fine powder. The resultant powder was sieved through a 250 MICS sieve to obtain a uniform particle size suitable for activation.

Preparation of Activated Charcoal

The powdered LCSP (*Livistona chinensis* seed powder) was activated through chemical treatment using concentrated H_2SO_4 in a 1:1 weight ratio, based on a modified procedure from previous studies [2,14]. This mixture was heated in an oven at 150 °C for 24 hours to facilitate carbonization and activation. After cooling, the material was ground and thoroughly washed with deionized water to remove residual acid. Subsequently, the material was dried at 105 °C and neutralized using a 1% $NaHCO_3$ solution. Neutralization was achieved by soaking the material until effervescence ceased, followed by an additional

24 hours soaking in the $NaHCO_3$ solution. The neutralized material underwent repeated washing with deionized water to ensure complete removal of bicarbonate residues and dried at 105 °C. The final product was sieved through a 150 MICS sieve to ensure uniformity. The prepared activated charcoal, designated as *Livistona chinensis* activated charcoal (LCAC), was stored for subsequent experiments on water purification. The synthesis process of LCAC is illustrated in **Figure 1.**

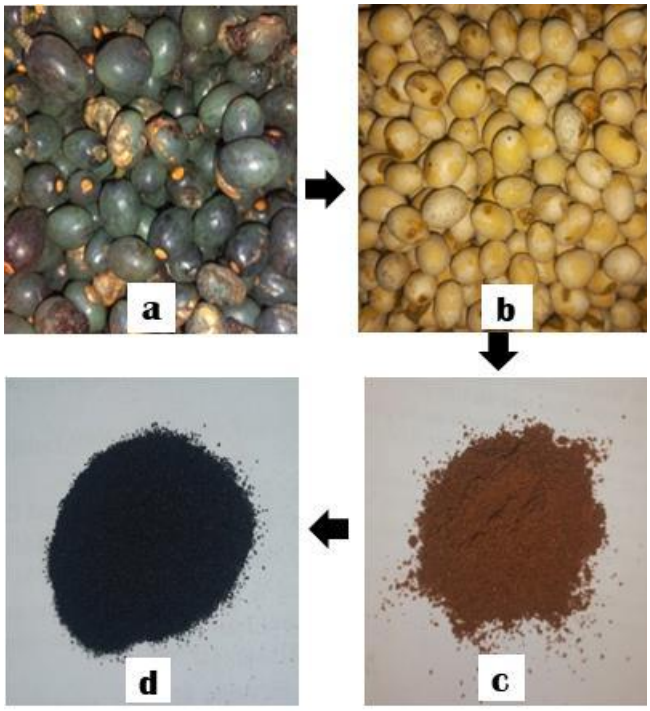

Figure 1: Photographs showing different steps involved during the preparation of activated charcoal from *Livistona chinensis* seeds: (a) Fruits, (b) Seeds, (c) Seed powder, and (d) Activated charcoal

Water Quality Testing using Activated Charcoal

The water purification process commenced with an assessment of various water quality parameters in untreated samples, following standard methodologies [23-26]. **Figure 2** illustrates the different stages involved in water purification using activated charcoal synthesized from *Livistona chinensis* seeds. For purification, 25 grams of activated charcoal were agitated with 500 mL of each water sample for 24 hours at 300 oscillations per minute using a Stuart SF1 Flask Shaker. The final stage involved analyzing the treated water for parameters such as pH, metal concentration, chloride content, and hardness to evaluate the effectiveness of the purification process. All the tests and characterizations were observed for the triplicate samples

pH

The pH of each water sample, before and after treatment, was measured in triplicate using a calibrated digital pH meter (ISO 9001:2015 Certified Company) with standard buffers (pH 4 and 7). Readings were taken after stabilization, and the mean value of three readings were reported to ensure accuracy and consistency.

Conductivity

Electrical conductivity (EC) of each water sample, before and after treatment, were measured using a calibrated digital conductivity meter (LABMAN Scientific Instruments) with standard KCl solution. The electrode was rinsed with distilled water before immersion, and readings were taken at 25 °C. Each measurement was performed three times, and the results were reported as the mean value to ensure accuracy and reproducibility.

Total Dissolved Solids (TDS)

TDS were determined using the gravimetric method. A clean, dry porcelain basin was accurately weighed, then 50 mL of filtered water sample was added. The basin was heated at 105°C until all moisture evaporated, cooled, and reweighed. Each measurement was performed three times, and the mean value was reported to ensure accuracy. The TDS in mg/L was then calculated accordingly.

Total Hardness

TH was determined using the EDTA titrimetric method. A 25 mL water sample was placed in a conical flask, followed by 2 mL of ammonia buffer and a few drops of Eriochrome Black T indicator. The sample was titrated with EDTA solution until the color changed from wine-red to blue, indicating the endpoint. The procedure was repeated three times, and the mean value was reported. The TH

concentration in mg/L was then calculated accordingly.

Chloride

Chloride concentration was determined by argentometric titration. A 50 mL water sample was placed in a conical flask, followed by the addition of 2 mL of 2% potassium chromate (K_2CrO_4) solution. The sample was titrated with standard silver nitrate ($AgNO_3$) solution until the color changed from yellow to brick orange, indicating the endpoint. Experiments were performed in triplicate, and the average value was reported to ensure accuracy and reproducibility. The chloride concentration in mg/L was then calculated accordingly.

Dissolved Oxygen

Dissolved oxygen was determined by the Winkler method. A 200 mL sample was collected in a BOD bottle without air bubbles. After adding 2 mL each of 20% alkaline KI and 50% $MnSO_4$, the bottle was stoppered, shaken, and allowed to stand. Then, 2 mL of 85% phosphoric acid was added to dissolve the precipitate. A 100 mL portion was titrated with $Na_2S_2O_3$ solution using starch as an indicator until the bluish-black color turned pale yellow. The procedure was repeated three times, and the concurrent value was recorded. The concentration in mg/L was then calculated accordingly.

Heavy Metals

The concentrations of iron (Fe), manganese (Mn), nickel (Ni), zinc (Zn), cadmium (Cd), and lead (Pb) were measured using a Flame Atomic Absorption Spectrophotometer (Agilent AA5-200 Series).

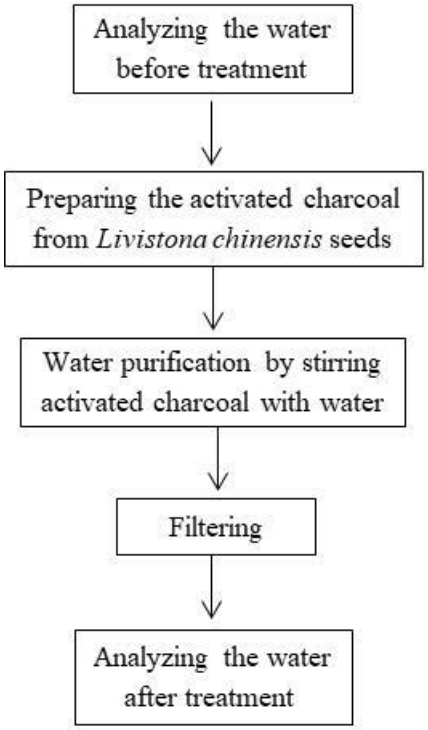

Figure 2: Flowchart summarizing steps for water analyses involved in the study

Characterization Techniques

Atomic Absorption Spectrophotomete (AAS) is a highly advanced and sensitive analytical technique widely used for the detection and quantification of heavy metals in water samples. In this study, Flame Atomic Absorption Spectrophotometer **(**Agilent AA5-200 Series**)** was employed due to its suitability for measuring metals such as Fe, Mn, Pb, Ni, Zn, and Cd in aqueous solutions. Calibration curves were prepared using standard solutions of each metal at different known concentrations to ensure accuracy and reliability of the analysis. Samples were aspirated into a flame, where the metal atoms absorbed light at their characteristic wavelengths. The absorbance values were measured and used to calculate the concentrations of heavy metals in the samples based on the calibration curves. The instrumental parameters, including wavelength, lamp current, and slit width, were optimized according to the manufacturer's guidelines. To ensure accuracy and reliability, blank samples were used to check for contamination, and all measurements were performed in triplicate

FTIR was utilized to analyze the surface chemistry of the precursor and the activated charcoal, with an emphasis on identifying functional groups. The analysis was performed using an FTIR spectrometer (Shimadzu IR Tracer-100, Japan) having a spectrum range of 400 cm $^{-1}$ to 4000 cm $^{-1}$ in attenuated total reflection (ATR) mode, providing detailed insights into the chemical functionalities of both materials. The AAS and FTIR analyses were conducted at the Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur.

Results and Discussion

FTIR Analysis of Surface Functional Groups

The FTIR spectra help identify the functional groups present in a sample of LCSP and LCAC. Each functional group has a unique vibration range that reveals the types of atoms or groups of atoms in the sample. The graph in **Figure 3 and 4** were created using Origin Pro-2024 software, based on data collected from FTIR scans. In the spectrum of LCSP, a peak at 3898 cm^{-1} corresponds to O-H stretching, indicating hydroxyl groups, while the peak at 2926 cm^{-1} is attributed to C-H stretching vibrations [14, 27]. The peak at 2360 cm^{-1} is due stretching vibration of carbon dioxide (O=C=O) [28]. The peak at 1612 cm^{-1} corresponds to C=C stretching, indicating the presence of unsaturated carbon structures [27, 29]. For LCAC, a broad band at 3587 cm^{-1} corresponds to O-H stretching, confirming the presence of hydroxyl groups [27, 30]. The peak at 2955 cm^{-1} represents C-H stretching, while the peak at 1709 cm^{-1} corresponds to C=O stretching, characteristic of carbonyl groups [27, 29]. Additionally, the peak at 523 cm^{-1}, associated with M-O stretching, reflects the activation process and enhanced adsorption properties. These changes highlight the role of activation in improving the surface chemistry of LCAC, making it suitable for water purification applications.

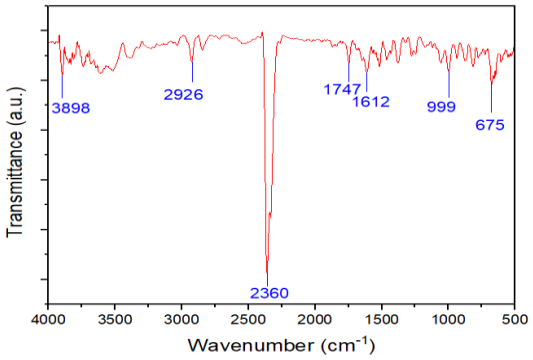

Figure 3: FTIR spectrum of *Livistona chinensis* seed powder (LCSP)

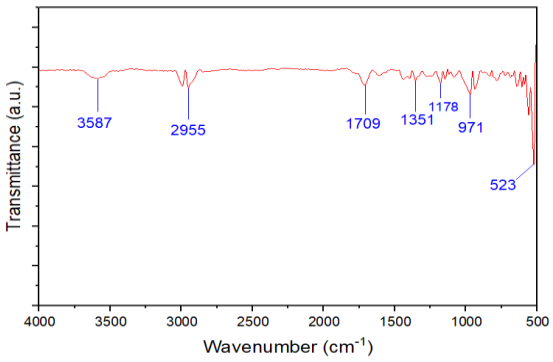

Figure 4: FTIR spectrum of *Livistona chinensis* activated charcoal (LCAC)

Water Analysis

Table 1 presents the results of water analysis before and after treatment using activated charcoal, where S_1 represents underground water and S_2 represents Ranipokhari water. The standard values referenced are based on the National Drinking Water Quality Standards (NDWQS) and WHO guidelines [31,32]. The results indicate the presence of heavy metals in water samples from Kathmandu Valley. Notably, the concentrations of Fe and Cd exceeded the acceptable limits set by WHO, highlighting potential health risks associated with untreated water consumption. Other physico-chemical parameters such as pH, EC, TDS, TH, chloride, and dissolved oxygen were within permissible limits before treatment. For both S_1 and S_2, there was a significant reduction in EC and TDS, demonstrating the charcoal's effectiveness in removing dissolved minerals and contaminants. Similarly, TH was

completely eliminated and Cl^- concentrations was decreased by 70-75% in both samples which reflected the charcoal's capacity to adsorb salt content and enhance water quality. Additionally, the activated charcoal effectively removed heavy metals, including Fe, Mn, Ni, and Cd, achieving complete elimination. These results confirm the effectiveness of activated charcoal in purifying water by significantly reducing both inorganic contaminants and heavy metals. The results of this study are consistent with previous research. For example, Jamilatun and Mufandi (2020) used activated charcoal derived from coconut shells for water purification and reported the complete removal of TDS, and Cl^-, and heavy metals, which aligns with the results observed in this study [21]. Similarly, Ajala et al. (2021) prepared activated charcoal from hamburger seed coats and demonstrated its high efficacy in removing contaminants, including TDS, TH, Cl^-, and heavy metals, in a manner similar to this study's findings [9]. Notably, in this study, the reduction in TH was nearly double the percentage observed in their work. Furthermore, Shrestha (2017) reported that activated carbon derived from Lapsi seed stones effectively removed heavy metals such as Pb, Ni, and Cd from aqueous solutions, which further supports the potential of activated charcoal from agricultural by-products for water purification [2]. However, the pH of the treated water was slightly acidic, likely due to the use of conc. H_2SO_4 in the activation process. Despite multiple washings, neutralization was incomplete, potentially affecting water quality. Future studies could explore alternative activation methods to minimize pH reduction. Overall, activated charcoal derived from *Livistona chinensis* seeds shows significant potential as an effective and cost-efficient material for purifying water by removing both inorganic contaminants and heavy metals.

Table 1: Statistical summary of drinking water quality parameters analyzed in water samples using activated charcoal.

Parameters	Units	S_1 before treatment	S_1 after treatment	S_2 before treatment	S_2 after treatment	NDWQS value	WHO guidelines value
pH		7.91	6.21	7.48	5.77	6.5-8.5	6.5-8.5
Electrical Conductivity	µS/cm	688	473.13	451.32	301.31	1500	-
TDS	mg/L	520	400	340	260	1000	-
Total hardness	mg/L	120	Nil	60	Nil	500	-
Chloride	mg/L	100.28	28.01	11.79	2.94	250	-
Dissolved oxygen	mg/L	9.79	6.91	15.55	11.17	-	-
Fe	mg/L	0.26	Nil	0.05	Nil	0.3	-
Mn	mg/L	0.43	Nil	0.004	Nil	0.2	0.08
Ni	mg/L	Nil	Nil	0.009	Nil	-	0.007
Cd	mg/L	Nil	Nil	0.004	Nil	0.003	0.003
Zn	mg/L	Nil	Nil	Nil	Nil	3	-
Pb	mg/L	Nil	Nil	Nil	Nil	0.01	0.01

Conclusions

Activated charcoal produced from *Livistona chinensis* seeds has demonstrated significant potential as an effective material for water purification. FTIR analysis confirmed successful activation, enhancing the adsorption capacity of the charcoal. Application of this material led to notable improvements in water quality, including reductions in EC, TDS, TH, chloride concentrations, and heavy metal content as verified by AAS analysis. These results suggest that *Livistona chinensis* seeds, as readily available agricultural waste and can be used as low-cost and environmentally friendly option for water purification. Future studies could explore for various production methods to further enhance the charcoal's adsorption capacity and performance. Further research is recommended to evaluate long-term performance, and assess scalability in real-world water treatment scenarios under different environmental conditions. Such studies will be crucial for advancing the practical application and wider adoption of this promising material.

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Author's Contribution Statement

S. Hatuwal: Methodology, Formal analysis,

Data curation, Writing-original draft of manuscript, **G. Aryal**: Writing-review and editing, **J. Giri**: Conceptualization, Writing-review and editing, Supervision

Conflict of Interest

The authors hereby declare that there are no conflicts of interest associated with this research.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding authors upon reasonable request.

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