1. Title:

Unlocking Livelihood Opportunities: A Model for Production and Commercialization of Essential Oils from Medicinal and Aromatic Plants

SUBMITTED BY

RUBBER RESEARCH INSTITUTE OF NIGERIA

TO

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2. ABSTRACT

Medicinal and aromatic plants are valuable reservoirs of fatty acids for food, health, and industrial uses. Their diversity is a natural capital from which the economy and society benefit. Valorizing medicinal plants for essential oil production is vital for Nigeria's local economy by boosting export revenue, creating jobs in cultivation and processing, fostering local industries, and reducing reliance on imported products, ultimately encouraging sustainable development and economic diversification. This process transforms raw plant materials into high-value products for cosmetics, food, and pharmaceuticals, capturing more value within the country instead of exporting raw materials at lower prices. In this proposal, we outline a comprehensive project aimed at the valorization of five specific indigenous Nigerian medicinal plants, some of which are grown within the Rubber Agroforestry system: *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera*, through the production of commercial-scale essential oils. To achieve this, the project will custom-design, fabricate, and operate a portable energy-efficient liquefied petroleum gas (LPG)-powered steam distillation unit and a small-sized automatic cold-press oil expeller machine. The essential oils extracted will undergo a multi-pronged scientific assessment, including detailed phytochemical profiling via Quadrupole Time-of-Flight Gas Chromatography-Mass Spectrometry (GC/Q-TOF-MS) and a comprehensive bioassay to evaluate their antimicrobial and antifungal properties against a range of pathogenic microorganisms. Furthermore, a critical and pioneering aspect of this project is the detailed economic analysis of the pilot-scale production process, which will rigorously examine direct and indirect costs, as well as potential profitability. This will serve as a foundational business case for the commercial-scale production of EOs, providing vital information to potential investors and entrepreneurs. To ensure the long-term sustainability of the venture and address the risk of dwindling raw material supply, the project will integrate a robust conservation and propagation strategy. This includes the implementation of both macro- and micro-propagation techniques and the establishment of an ex-situ conservation site. The project is designed not only to advance scientific and technological knowledge but also to foster locally-initiated industrialization, create a skilled workforce through the training of stakeholders, including contract farmers who will grow and supply the raw materials, ultimately contributing to national health and food security, thereby aligning directly with NASENI's core mandate and the renewed hope agenda of promoting developmental work in manufacturing, and engineering infrastructure towards unlocking livelihood opportunities.

Keywords: Valorization, Medicinal and Aromatic plants, Indigenous plants, Conservation, Biodiversity, Production and Commercialization.

3. Introduction and Background

Integrating medicinal plants into Rubber agroforestry systems enhances biodiversity, improves soil health, and provides sustainable income for farmers through the sale of herbal medicines and products (Kholiya et al., 2025). This approach creates a more resilient farming system by diversifying income streams, ensuring food security, and contributing to climate change mitigation. Medicinal plants that tolerate shade, such as those from the Zingiberaceae, Mentha, or Cymbopogon genera, are particularly suitable for integration into Rubber agroforestry designs, particularly due to the long juvenile phase of the Rubber Tree, typical of alley cropping systems (Cahyo et al., 2024; Zou et al., 2025). Many of these indigenous medical plants with nutritional-nutraceutical potentials are undervalued, neglected, and underutilized (Mungofa et al., 2022). Although used for centuries by indigenous people in traditional ways for the treatment of various ailments, most of the medicinal plants were neither domesticated nor characterized in Nigeria (Kadiri and Olawoye, 2015); often, they are endangered and/or threatened in the wild and might go into extinction if nothing is done to rehabilitate and valorize them (Mudau et al., 2022; Ezea et al., 2025). The idea behind the proposed research project is to popularize the medicinal and aromatic agroforestry model developed at RRIN (Asaah et al., 2014, Esekhade et al., 2019), at the same time conserve and use sustainably some indigenous medicinal plants, e.g., *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera*; and develop value-added products, particularly essential oils from the plant materials. These oils are invaluable for use in pharmaceutical, agricultural, sanitary, and food industries, thereby contributing to national food and health security (Hyldgaard and Alotaibi, 2012; Nazir and Ahmad, 2022; Mohamed et al., 2023). Specifically, the project is targeting these medicinal plants because of their potential for use as antibacterial, antifungal, antiparasitic, antidiabetic, anticancer (cytotoxic), insect repellent, flavoring, aromatherapy, antioxidant, perfume, and cosmetic properties (Mu'azu, et al., 2019; Parham et al., 2020; Osazuwa et al., 2025). Here, our first hypothesis is that valorization of *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera*, through steam distillation, can provide high-quality pure essential oils that could have broad application in food and health sectors, raising the potential to improve the profile of these indigenous medicinal plants. Secondly, fatty acids and phytochemical profiling of the various essential oils could reveal EO constituents that could be potential targets for drug discovery (Chen et al., 2017), thereby establishing the theoretical basis for process enrichment of specific EO constituents for application as natural remedies. Thirdly, the economic analysis of production costs (direct and indirect) and the expected net profit or loss of EO production at the pilot scale will reveal the challenges and profitability of setting up a potential enterprise for EO production from the above-mentioned medicinal plants. Overall, this study has the potential to provide a crucial theoretical basis for the future engineering of large-scale steam distillation infrastructure for EOs production at the Rubber Research Institute of Nigeria.

3.1. Problem Statement

Nigeria is endowed with a rich and diverse flora, yet a significant portion of its indigenous medicinal plants remain underutilized and neglected. Plants such as *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera* have been used for centuries by indigenous communities for their therapeutic properties, including anti-bacterial, anti-fungal, anti-inflammatory, and anti-diabetic effects. However, a critical lack of awareness regarding their specific bioactive constituents and the absence of a structured, value-added processing chain have left these valuable resources on the verge of extinction. Currently, Nigeria's essential oil market is in its nascent stage and is heavily reliant on imports. This overdependence on foreign products represents a significant economic leakage and underscores a major gap in the nation's industrial capacity. The absence of local technology and infrastructure for essential oil extraction and characterization has created a substantial barrier to entry for potential entrepreneurs and has prevented these plants from contributing meaningfully to the national economy and food systems. This project seeks to address this fundamental problem by bridging the gap between traditional knowledge and modern scientific and engineering applications, thereby creating a pathway for the sustainable and commercial utilization of these valuable flora.

3.2. Justification / Relevance to NASENI Priority Areas

This project directly advances NASENI's strategic goal of fostering homegrown industrialization by demonstrating Nigeria's capacity to design, fabricate, and validate essential manufacturing equipment. The development of a pilot-scale steam distillation unit not only fulfills NASENI's mandate in manufacturing innovation and capital goods engineering but also provides a practical blueprint for reducing dependence on imported machinery. By building the infrastructure needed for essential oil production locally, the project showcases how indigenous engineering solutions can catalyze new industries and strengthen Nigeria's technological self-reliance. Additionally, the project goes beyond the simple production of a product; it aims to catalyze the development of a new industrial ecosystem within Nigeria. By moving the project from a research idea to a pilot-scale prototype, it will serve as a crucial proof-of-concept for the viability of a domestic essential oil industry. The economic analysis, a key component of the methodology, is designed to generate data on production costs and profitability. This data will be instrumental in demonstrating the business case to private investors and fostering new enterprises. The success of this initiative would validate the potential for a domestic manufacturing industry for both the final products (essential oils) and the means of production (the distillation units). This approach directly addresses NASENI's goal of achieving high R&D output that generates revenue and has a direct impact on national economic development. Furthermore, this project represents the convergence of scientific research and socio-economic progress. It bridges scientific innovation and economic development by generating critical data on essential oil quality through phytochemical analysis and bioassays, key to commercial viability. It also builds local capacity by training stakeholders and contract farmers in extraction, analysis, and propagation techniques, creating a skilled workforce for the future industry.

4. Technology Readiness Level (TRL) Assessment

4.1. Current TRL Stage

The current state of this project is assessed at TRL 3: Experimental Proof of Concept. This is based on the fact that the fundamental principles of essential oil extraction via steam distillation are well-established, and the medicinal properties of the target plants have been documented in existing scientific and ethnobotanical literature. The project's core hypothesis, that the valorization of these specific plants through this proven method can yield high-quality, commercially viable essential oils, has a strong theoretical foundation. The project is at the stage of formulating a specific application and developing the first experimental proof-of-concept.

4.2. Achievements to Date

To date, the primary achievement is the successful completion of the foundational research and planning phase. This includes:

- Extensive literature review and ethnobotanical surveys to identify and validate the potential of *Aframomum Danielli*, *Ocimum gratissimum*, *Cymbopogon citratus*, *Indigofera tinctoria, and Moringa Oleifera* for essential oil production.
- Conceptualization of the entire project workflow, from plant sourcing to product dissemination, as detailed in the conceptual framework.
- Formulation of a comprehensive and detailed methodology, including specifications for the steam distillation unit, analytical procedures, and conservation strategies.

4.3. Target TRL Stage

The project's goal is to advance to TRL 5: System Component and/or Breadboard Validation in a Relevant Environment. By the conclusion of the project, the custom-fabricated steam distillation unit will be fully operational and validated through the successful extraction of essential oils from the four target plants. This will demonstrate the functionality and viability of the technology in a realistic, pilot-scale setting, laying the groundwork for a future scale-up to a commercial production facility at the Rubber Research Institute of Nigeria (RRIN).

5. Objectives

5.1. General Objective

The overarching objective of this study is to contribute to national health and economic security by establishing a sustainable, locally-initiated industrial model for the commercial production of high-quality essential oils from underutilized indigenous medicinal and aromatic plants.

5.2. Specific Objectives

Pilot-Scale Objectives:

- To produce high-quality, pure essential oils from the seeds, leaves, stalks, and roots of *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera* at a pilot scale using the steam distillation method.
- To design and fabricate a portable steam distillation unit powered by Liquefied Petroleum Gas (LPG), demonstrating an efficient, locally adaptable technology.
- To perform a comprehensive qualitative and quantitative analysis of the phytochemical constituents of the extracted essential oils using GC/Q-TOF-MS.
- To assess the antimicrobial and antifungal activities of the essential oil extracts through in vitro bioassays against a range of bacterial and fungal pathogens.
- To conduct a rigorous economic and profitability analysis of the pilot-scale production process to determine its commercial viability and provide data for future enterprise development.
- To provide a crucial theoretical basis for the future engineering of large-scale steam distillation infrastructure for EO production at the RRIN.
- To train and mentor stakeholders and contract farmers on essential oil extraction and analytical techniques, thereby contributing to human capital development.

Long-Term Cultivation and Conservation Objectives:

- To develop and implement micro- and macro-propagation protocols for the large-scale production of the medicinal plants, ensuring a sustainable supply of raw materials.

- To establish an ex-situ conservation site at the Rubber Research Institute of Nigeria, an arboretum to protect and rehabilitate these threatened species.
- To provide hands-on training for three RRIN staff on micro- and macro-propagation techniques.

6. Methodology / Research Plan

6.1. Experimental Design / Approach

The project will follow a systematic and integrated conceptual framework to achieve its objectives, as illustrated in the provided schematic. The workflow is a linear progression, beginning with raw material sourcing and preparation. This is followed by the engineering phase, which involves the design and fabrication of the steam distillation unit. The third phase is the operational and analytical stage, where essential oils are extracted, characterized, and tested for their biological activities. A parallel and equally important track of the project focuses on conservation and propagation, ensuring that the research contributes to the long-term sustainability of the plant species.

6.2. Materials and Methods

Study Area and Plant Material Sourcing: The study site is at RRIN, and plant materials include *Aframomum Danielli, Ocimum gratissimum, Cymbopogon citratus, Indigofera tinctoria, and Moringa Oleifera,* which will be sourced from diverse geographical locations to ensure a representative sample of each species.

- *Aframomum Danielli* and *Ocimum gratissimum* will be obtained for the RRIN Rubber plantations at Iyanomo.
- *Cymbopogon citratus* materials will be collected from the home gardens and natural forest habitats in Edo, Delta, Abia, Imo, and Enugu States.
- *Indigofera tinctoria* will be collected from the Esa-edo, Oshogbo, and other parts of Osun and Edo States.
- Moringa oleifera materials will be sourced from Kaduna, Bauchi, Oyo, and Ogun States. The collected plant materials will be prepared according to European Pharmacopeia standards, involving air-drying to facilitate the liberation of oils from plant cells.

Design and Fabrication of Portable Steam Distillation Unit: The project will involve the detailed process and mechanical design of a pilot-scale steam distillation unit. This unit will be fabricated using

- 304/316 stainless steel grade to ensure durability and prevent contamination. The plant will consist of an extraction vessel, a steam boiler, a condenser unit, a gas-fired burner, and an oil separator. The design will leverage established engineering principles for efficiency and will include temperature and pressure indicators for process control. The use of LPG as the energy source will be a key parameter for the economic analysis.

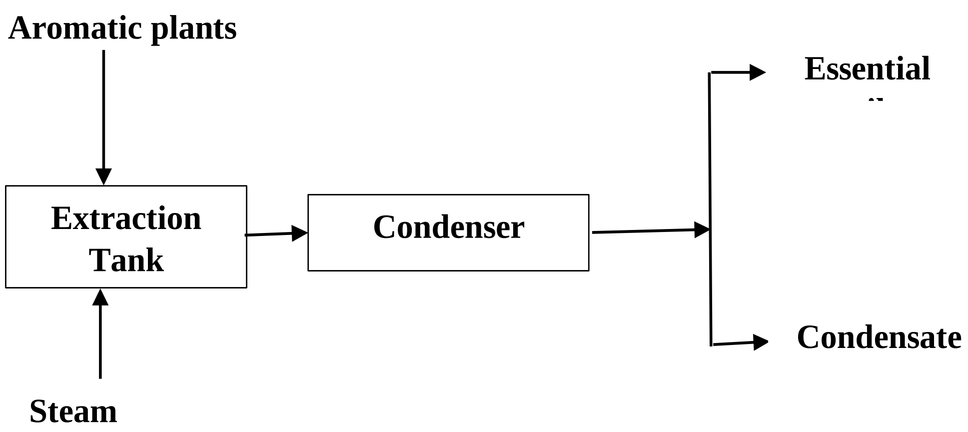

Figure 1: Block diagram for the production of essential oil from aromatic plants using the steam distillation technique.

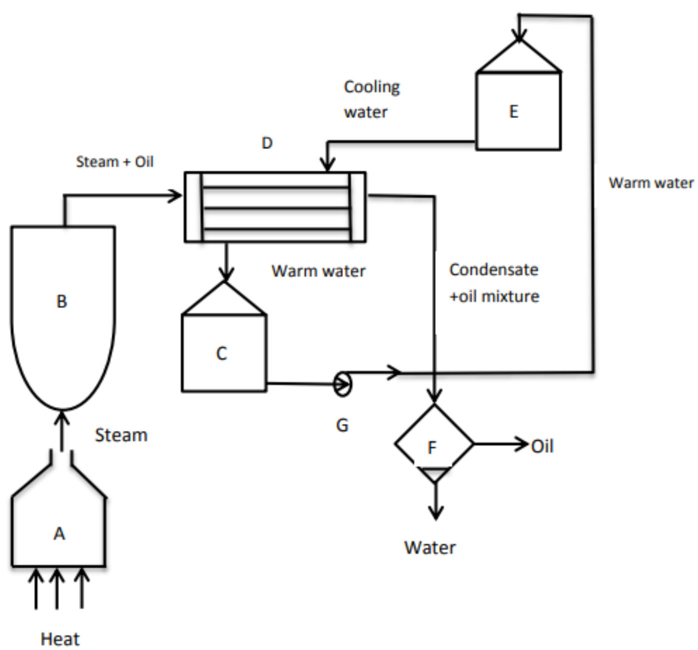

Figure 2: Process flow for steam distillation of essential oils from aromatic plants. A-Stem boiler, B-Oil extraction vessel, C-Water storage tank, D-Condenser, E-Water storage tank, F- Aspirator and G-Water pump.

Design and Fabrication of Portable Screw Type Cold-Press Oil Expeller Unit: The oil expeller uses a mechanical process that extracts oil by applying high pressure to raw materials (nuts and seeds) in a single step. Commonly used for food oil production.

- Several key components will be identified to ensure functionality and efficiency. The screw expeller shaft, typically featuring a square thread profile, is designed to apply pressure through rotation. Surrounding it is the expeller barrel, a robust cylindrical structure with a friction-enhancing internal surface to prevent slippage, often segmented for ease of maintenance. At the discharge end, a choke mechanism with an adjustable cone and handwheel allows for precise control of cake discharge and internal pressure. Seeds or nuts are fed into the system via the hopper, while a sturdy support frame, commonly constructed from angle iron, secures all components in place. Finally, the expelled oil is collected in a steel tray or similar oil collection system, completing the setup.

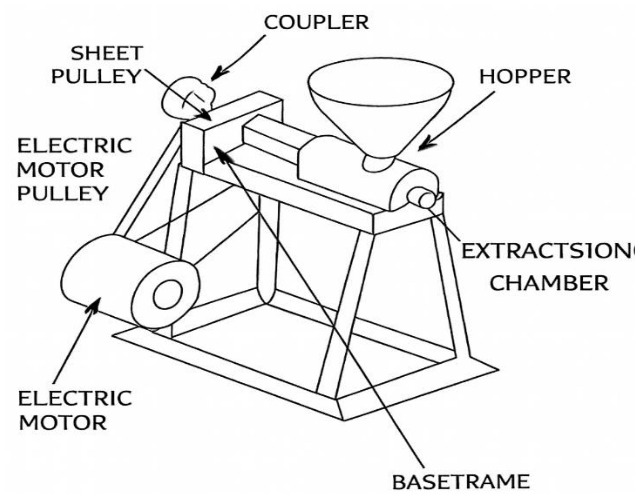

Figure 3: Isometric diagram of a cold-press oil expeller machine

Extraction of Essential Oil: The extraction will be performed in batches using the fabricated unit, with water vapor serving as the solvent. The process will involve passing hot steam through the prepared plant material to vaporize volatile compounds, which will then be condensed back into a liquid form and collected in an oil separator.

- Physical and Chemical Properties of Extracted EOs: The physical properties of the extracted oils, including appearance, refractive index, specific gravity, and color, will be determined using standard methods. Key chemical properties such as Iodine value, Saponification value, Acidic value, and Phenol content will also be assessed.

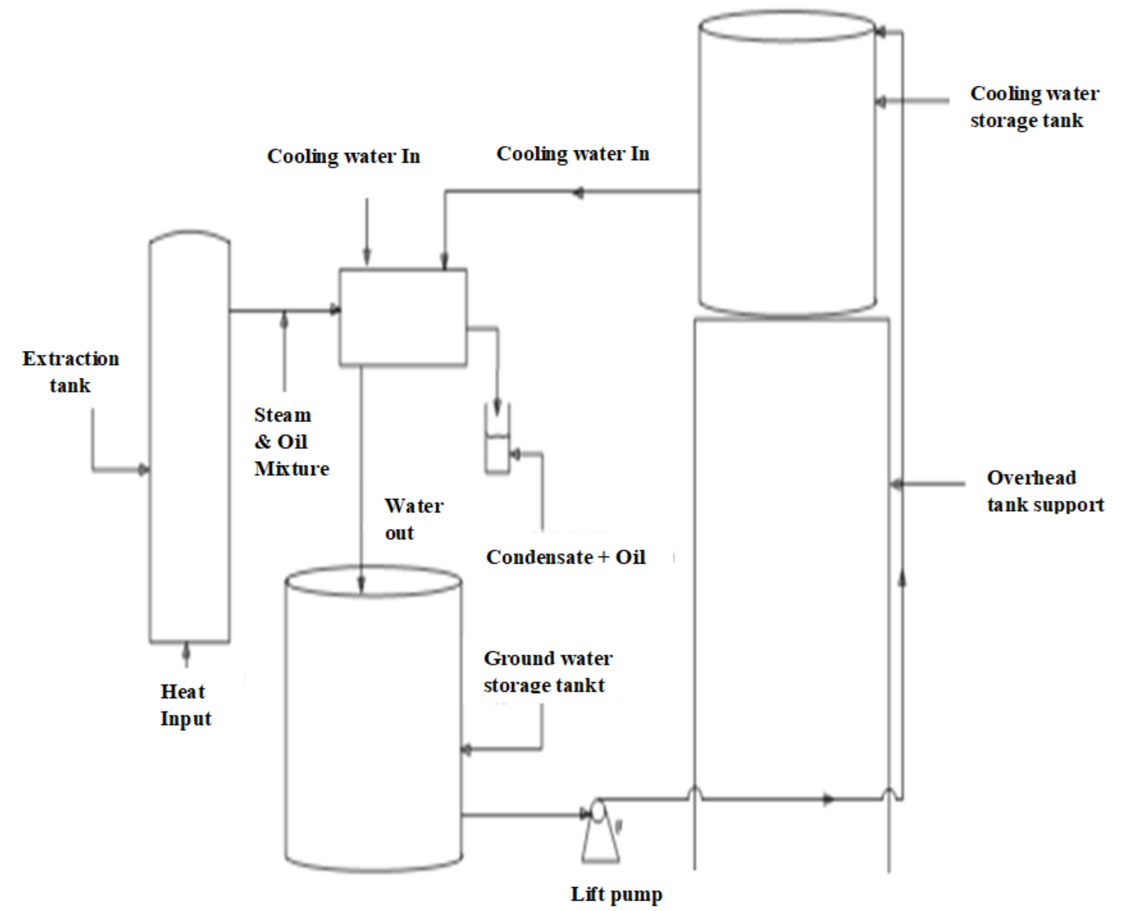

Figure 4: Schematic diagram of a portable steam distillation unit for essential oil production from medicinal plant tissues.

Macro and Micropropagation: To address the long-term sustainability of the project, a dual-pronged approach to propagation will be implemented.

- Macro-propagation will involve traditional methods using seeds and stem cuttings. Soil will be collected from the species' natural sites and analyzed before planting.
- Micro-propagation will be conducted at the NIFOR biotechnology laboratory in Edo State. A Completely Randomized Design (CRD) will be utilized with three replicates for each plant, testing different concentrations of growth regulators (auxins and cytokinins) on a gelled Murashige and Skoog (MS) medium. The process will include sterilization of explants, inoculation, shoot multiplication.
- ex vitro rooting and acclimatization, with the final hardened plantlets transferred to an ex-situ conservation site at the RRIN.

6.3. Data Collection and Analysis

Gas Chromatography-Mass Spectrometry (GC-MS/MS) Analyses: Phytochemical profiling will be conducted on the pure EOs using GC-FID and GC-MS/MS equipment. The analysis will employ a nonpolar HP-5 MS capillary column and a fused silica HP Innowax column with helium as the carrier gas. Individual compounds will be identified by comparing their mass spectra with internal reference libraries and confirmed using retention indices, as per standard protocols.

Bioassay (Antibacterial and Antifungal Activity): The biological activity of the EOs will be tested against four standard pathogenic microorganisms: Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans. The agar well diffusion method will be used to determine antimicrobial activity, with inhibition zone diameters measured to assess efficacy. The study will also test the EOs against five fungal strains of agro-food interest obtained from Dschang University, Cameroon.

Production Cost and Profitability Analysis: The economic analysis will be a cornerstone of the project's business case. The quantity of LPG utilized per batch will be measured to calculate energy utilization and cost, using the standard calorific value of 46.1 MJ/kg for LPG. This will be used to determine the total production cost and analyze the expected net profit or loss, providing concrete data on the challenges and profitability of a potential enterprise.

$$Q = W_1 \text{ (kg)} - W_2 \text{ (kg)} \qquad \text{Equation (1)}$$

The energy utilization, U (in MJ) per batch was thereafter obtained from Equation (2).

$$U = Q \times CV \qquad (2)$$

where Q is the quantity of gas consumed (kg) and CV is the calorific value of gas in MJ/kg and has a value of 46.1MJ/kg for LPG.

Statistical Analysis: All data obtained will be subjected to rigorous statistical analysis using R software. Descriptive statistics such as mean and standard deviation will be calculated for replicates, and a one-way analysis of variance (ANOVA) will be employed to compare the mean inhibition zone diameters across different concentrations.

7. Feasibility and Business Case

7.1. Market Potential

The feasibility of this project is high, given the significant market opportunity in Nigeria. The local essential oils market is currently in its infancy and heavily relies on imported products to meet the growing consumer demand in the health, nutrition, and cosmeceutical sectors. This over-reliance on imports, as noted in the research, represents a substantial deficit that can be addressed through local production. The project's business case is not predicated on creating a new market, but rather on capturing an existing, multi-million-dollar market share currently dominated by foreign suppliers. The detailed economic analysis will provide the necessary data to demonstrate the profitability of a local enterprise, thus providing a crucial and compelling argument for investment.

7.2. Commercialization Strategy

The commercialization strategy is anchored in a phased approach. The initial pilot-scale production serves as a proof-of-concept and data collection phase. The project's profitability analysis, which will measure direct and indirect costs and expected net profit, will be used to develop a comprehensive business plan for scaling the operation. The products will be promoted through peer-reviewed publications, presentations at national and international conferences, and showcased at local exhibitions and trade fairs. Additionally, a social media advertising campaign will be launched to raise public awareness and promote the extracted EOs. The long-term sustainability will be ensured by the establishment of the ex-situ conservation site, which will provide a consistent and secure supply of raw materials for a commercial enterprise.

7.3. Risk Assessment and Mitigation

The project's potential risks and their mitigation strategies have been carefully considered.

- **Raw Material Scarcity:** Given that some of the target plants are threatened, a major risk is the inconsistent or limited supply of raw materials. This is effectively mitigated by the project's long-term objective of establishing micro- and macro-propagation protocols and an ex-situ conservation site, which will ensure a sustainable supply for future production.
- **Technical Failure:** The fabrication and operation of the pilot-scale steam distillation unit carry a technical risk. This is mitigated by engaging experienced engineers for the design and construction, as well as a process flow expert for installation and testing.
- **Market Acceptance:** There is a risk that locally produced EOs may face resistance in a market accustomed to imported products. This is mitigated by the project's focus on rigorous scientific characterization using GC-MS/MS, which will provide data to validate the quality and purity of the EOs against international standards. This scientific validation will build consumer and industry confidence.

8. Project Work Plan and Timeline

The project activities are scheduled over 24 months, as detailed in the Gantt chart below. This timeline ensures a logical progression of tasks from initial plant sourcing to final report and dissemination, demonstrating a well-managed approach to project execution.

Table 1: Project Work Plan and Timeline (Gantt Chart)

Activity	2026	2027	
Sourcing of plant materials	June-August		
Sorting, drying & bulking of plant materials	Sept-Nov		
Tagging, batching & batch ID allocation	Sept-Nov		
Design & fabrication of steam distillation Unit and seed oil expeller machine		Dec-Mar	
Installation, testing, running, and troubleshooting		Apr-Jun	

EOs extraction (Thermal control extraction)		Jul-Sep	
EOs phytochemical profiling (GC-MS/MS analysis)		Oct-Dec	
Antimicrobial analysis of EOs			Jan-Feb
Economic analysis of EO extraction pattern/yield			Jan-Feb
Production cost & Profitability analysis			Jan-Feb
Micro & macro propagation			Mar-Jun
Stakeholder and Farmer Training			Mar-Jun
Conferences, workshops, ad campaigns & local exhibitions & Marketing			Mar-Jun
Project report and Manuscript writing for publication			Mar-Jun

9. Expected Outcomes and Impact

9.1. Scientific / Technological Contributions

The project is expected to deliver a variety of scientific and technological contributions. A fully functional, locally fabricated, pilot-scale steam distillation unit and an automatic cold-press oil expeller machine will be a permanent addition to the Rubber Research Institute of Nigeria's research infrastructure. The research will generate a new and comprehensive body of data on the phytochemical composition and antimicrobial activities of essential oils from four underutilized indigenous plants. These findings will be disseminated through publications in reputable international and local journals, as well as through presentations at scientific conferences, enriching the global body of scientific knowledge.

9.2. Socio-economic Impact

The project's socio-economic impact is expected to be significant and far-reaching. By providing a blueprint for a new industry, the initiative will create avenues for entrepreneurship and job creation. The training of two postgraduate students in extraction and analytical techniques, as well as the training of undergraduate and postgraduate students in propagation methods, will equip a new generation of scientists and technicians with marketable, industry-ready skills. The project will also transfer scientific knowledge directly to the public and potential entrepreneurs through local exhibitions, trade fairs, and media campaigns, fostering a culture of innovation and commercialization.

9.3. Contribution to National Development Goals

The successful completion of this project will contribute directly to several of Nigeria's national development goals. By identifying and characterizing EOs with potential health benefits and establishing a local production capacity, the project supports a move towards self-sufficiency in natural health products, thereby strengthening national health security. The potential use of these EOs as food antioxidants and preservatives will enhance food safety and preservation, contributing to national food security. The project's dual focus on industrial development and biodiversity conservation aligns with Nigeria's environmental commitments and vision for sustainable development. This project serves as a practical model for how

NASENI's mission of fostering home-initiated industrialization can be achieved by converting Nigeria's natural resources into value-added products and capital goods.

10. Budget Estimation

The total estimated budget for this 24-month project is one hundred and ten million, eight hundred and forty-nine thousand Naira only (**₦110,849,000)**. This figure has been meticulously calculated to ensure accuracy and encompasses all necessary expenses, from personnel and supplies to equipment, travel, and conservation costs. The detailed breakdown below provides a transparent allocation of funds across all project activities.

Table 2: Proposed Budget Breakdown

S/No.	Description of line item	No./Quantity	Unit cost (N)	TOTAL (N)
A	**Personnel Cost**			
1	PI	1	50,000/month x 24	1,200,000
2	CO-PIs	3	45,000/month x 24	3,240,000
3	Research assistants (Laboratory)	5	40,000/month x24	4,800,000
4	Field assistants	6	40,000/month x 24	5,760,000
	Sub-Total			**15,000,000**
B	**Supply Expenses**			
1	Sourcing of plant materials	5 (250kg/bag)	300,000/bag x 5	1,500,000
2	Fungal strains	8	50,000/box	400,000
3	E-coli strain	8	50,000/box	400,000
4	Fungal susceptibility testing kits	8	80,000/kit	640,000
5	Bacteria susceptibility testing kits	8	100,000/kit	800,000
6	Sterile 20ml plastic tubes	5	50,000/box	250,000
7	Sterile 15ml glass tubes	10	50,000/box	500,000
8	Box of 96 well plate	10	40,000/box	400,000
9	Murashige & Skoog Macronutrient Stock Solution (10x)	10	50,000/1L	500,000
10	Murashige & Skoog Modified Vitamin Solution (1000x)	10	30,000/1L	300,000
11	NaOH	1	30,000/kg	30,000
12	KaOH	1	40,000/kg	40,000
13	Agar	1	80,000/kg	80,000
14	Sucrose	1	30,000/kg	30,000
15	HCl	2	30,000/g	60,000
16	Tris Base	100	300/g	30,000
17	H_2SO_4	5	7,000/L	35,000
18	D-Biotin	1	10,000/kg	10,000
19	Zinc Chloride	3	10,000/kg	30,000
20	Sodium Carbonate	2	10,000/kg	20,000
21	Ethanol	5	20,000/L	100,000
22	Bleach	5	20,000/L	100,000
23	Adhesive tape	20 pieces	20,000/box	400,000
24	Forceps or tweezers	10	10,000/box	400,000

25	Gloves	10	10,000/box	100,000
26	Scalpel blade	10	30,000/box	30,000
27	Razor blade	20	20,000/box	400,000
28	Paper towel	20	5000/box	100,000
29	Naphthalene acetic acid	2	80,000/kg	160,000
30	Indole -3- acetic acid	2	280,000/g	560,000
31	2,4-Dichlorophenoxyacetic acid	2	300,000/kg	600,000
32	Benzyl amino purine	2	340,000/kg	770,000
33	Safranine	3	10,000/bottle	30,000
34	Pathogenic bacteria	10	20,000	200,000
35	Pathogenic fungi	10	20,000	200,000
	Sub-Total			**10,205,000**
	SDU & CPOE Production Line Materials			
36	Tags, ropes, and 5ml bottles	3 boxes	100,000/box	300,000
37	Buckets	4 dozen	85,000	340,000
38	Plastic polybags	3 boxes	20,000	60,000
39	Basins	10	20,000	200,000
40	Trays	10	15,000	150,000
41	Trolley	10	100,000	1,000,000
42	LPG	120kg	1300/Kg	156,000
43	Dissemination & awareness	5 weeks	650,000/Week	3,250,000
44	Product development, & branding & Marketing	3	2,000,000	6,000,000
	Sub-Total			**11,456,000**
C	**Equipment and Tests**			
1	Process design of all the equipment/unit	1	600,000	600,000
2	Mechanical design of the process equipment	1	400,000	400,000
3	Optimization using DWSIM software	1	250,000	250,000
4	304/316 Stainless steel plate (4mm)	6	1,300,000	7,800,000
5	304/316 Stainless steel plate (10mm)	4	1,150,000	1,460,000
6	¾-in Stainless steel pipe	20	85,000	1,700,000
7	Temperature indicator	10	100,000	1,000,000
8	Pressure indicator	4	150,000	600,000
9	Stainless steel valve	20	50,000	1,000,000
10	Stainless steel mesh	20	65,000	1,300,000
11	4-in Stainless steel pipe	30	95,000	2,850,000
12	Stainless steel electrode	30 pack	80,000	2,400,000
13	Stainless steel Nuts & bolts	150	5000	750,000
14	Mild steel angle iron	100	50,000	5,000,000
15	Industrial burner and accessories	3	200,000	600,000
16	Insulator	5	100,000	500,000
17	Sheet of Gasket	2	225,000	450,000
18	1000L-GeePee tank	4	250,000	1,000,000
19	PVC pipes	30	10,500	315,000
20	Plumbing accessories	10 kits	100,000	1,000,000

21	0.5hp pump	5	350,000	1,750,000
22	4-liter transparent glass	5	160,000	800,000
23	12.5kg LPG gas cylinder with accessories	6	25,000	150,000
24	1 drum of diesel	600 Liters	2,250/liter	1,350,000
25	Labour for fabrication	25	100,000	2,500,000
26	Transportation for procurement	5	300,000	1,500,000
27	Transportation for conveyance	5	800,000	4,000,000
28	Consumables	30	200,000	6,000,000
29	Installation and test running fee	1	500,000	500,000
30	Water supply and electricity cost	1	100,000/month x 12	1,200,000
31	GenStat software	1	100,000	100,000
32	Graduated cylinder	10	50,000	500,000
33	Scale	5	65,000	325,000
34	GC-MS/MS analysis	60 samples	250,000/sample	15,000,000
35	Laptop (HP 250 G7)	2	1,000,000	2,000,000
	Sub-Total			**68,650,000**
D	**Transportation & Travels**			
1	Transportation of raw materials	5	250,000	1,250,000
2	Transportation of samples to NARICT for analysis	1	200,000	200,000
	Sub-Total			**1,450,000**
E	**Conservation costs**			
1	Bench fee for Biotechnology Lab RRIN	2 Staff trainees	500,000	1,000,000
2	Peat moss	5-50kg bag	100,000	500,000
3	Shredded Coconut Husk	2-10kg bags	40,000	80,000
4	Soilrite	7-50kg bag	100,000	700,000
5	Potting soil (Humus soil)	5-50kg bag	60,000	300,000
6	Cotton twine	4 Rolls	30,500	140,000
7	Paper cups	5 boxes	50,000	250,000
8	Plastic polybags	5 boxes	30,000	150,000
9	Materials used for macro-propagation			
10	Pruning Shears	3	30,000	90,000
11	Watering can	3	40,000	120,000
12	Measuring tapes	3	5,000	15,000
13	Machetes and a kitchen knife	4	15,000	60,000
14	Plastic film	4 cartons	30,000	120,000
15	Fence materials (wire gauze)	100 meters	160,000	1,600,000
16	Nets (meter sq)	1,200 meters	15000	180,000
17	Bag of nails	3	10,000.00	30,000
18	Woods and frames	15	12,000.00	1,800,000
19	Shovel	10	14,000.00	140,000
20	Personal protective equipment (PPE)	15	80,000	1,200,000
21	Ex-situ conservation site mapping, preparation, and clearing	1	300,000.00	300,000.00

22	Maintenance and management of ex-situ conservation site	1	500,000	500,000
	Sub-Total			**9,275,000**
	Miscellaneous			1,040,000
	Overhead			5,229, 000
	Grand Total			**110,849,000**

11. Team and Institutional Support

11.1. Research Team Profile

The project will be led by a highly competent and multidisciplinary research team. The Principal Investigator (PI) will assume responsibility for overall project coordination, management, and strategic oversight. The team includes three Co-Principal Investigators (CO-PIs) who will provide specialized expertise in their respective domains, such as Process engineering, plant biotechnology, chemical analysis, and economic feasibility. The project will also employ two laboratory research assistants and two field assistants to support the day-to-day experimental work, material sourcing, and data collection.

Research Team Profile

S/N	Names	Designation/Area of Specialization
	RRIN TEAM	
1.	Dr. L.N. Dongo	Chief Executive Director
2.	Dr. K.O. Omokha~~fe~~	Director/Plant Breeder
3.	Dr. O. Emuedo	Director/HOD Research Operation
4.	Dr. Eseosa Osazuwa	Asst. Director / Programme Leader
5.	Dr. E. O Uzunuigbe	Asst. Director / Programme Leader
6.	Dr. C.C. Nwafor	Senior Research Officer/Project Leader
	NARICT TEAM	
7.	Dr. Engr. Kabiru Muazu	Director General
8.	Dr. Engr. Etukessien Stephen Akpan	Asst. Director / Process flow engineering
9.	Dr. Engr. E. Otsai	Asst. Director / Engineering Design

11.2. Institutional Facilities and Infrastructure

The project will be carried out at the Rubber Research Institute of Nigeria (RRIN), and the National Institute for Chemical Technology (NARICT), Zaira, leveraging their existing facilities to minimize overhead costs.

The RRIN will provide laboratory space, electricity, and water supply from its existing infrastructure. NARICT engineering lab will ensure the expert design and fabrication of the steam distillation and seed oil expeller machines. The RRIN Biotechnology Laboratory offers established and well-equipped facilities for tissue culture and micropropagation experiments. Additionally, the RRIN arboretum will be utilized to establish the ex-situ conservation site, providing a secure and protected environment for the cultivated plants. This institutional collaboration ensures access to the necessary infrastructure and expertise for the project's success.

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