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Financial Feasibility and Cost Optimization of Neem-Pongamia Oil Nanoemulsion as a Sustainable Biopesticide

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Abstract - Concerns about environmental sustainability and the need for safer, plant-based alternatives have been raised by the growing usage of conventional chemical pesticides in agriculture. The bioactive qualities of neem (Azadirachta indica) and pongamia (Pongamia pinnata) oils make them attractive options for environmentally friendly biopesticide applications. The previously created neem–Pongamia oil nano emulsion served as the technical basis for assessing the production economics and financial viability of the current investigation.The study identifies key cost factors that could affect the nano emulsion's commercial viability and looks further at how production scale affects unit cost. A more comprehensive evaluation of the shift from laboratory-scale product development to possible commercial manufacturing is obtained by combining the current experimental results with cost and financial analysis. The study's objectives are to ascertain whether neem–Pongamia oil nano emulsion can be manufactured at a cost that is economically feasible and to pinpoint prospects for cost reduction, operational enhancement, and potential commercialization as a sustainable biopesticide.

Key Words: Neem (Azadirachta indica); Pongamia (Pongamia pinnata); Nano emulsion; Biopesticide; Sustainable Agriculture; Antimicrobial Activity; Cost Analysis; Financial Feasibility; Cost Optimisation; Break-Even Analysis; Production Scalability; Commercialisation

1.INTRODUCTION

Food production, rural livelihoods, and economic growth are all greatly aided by agriculture. Numerous variables, such as fungi, insects, pests, and bacterial diseases, can lower crop productivity and quality. Conventional chemical pesticides have been utilized extensively to control these issues due to their quick and efficient action. Concerns about the long-term consequences on agricultural ecosystems, pesticide residues, effects on beneficial creatures, and environmental sustainability have been raised by the persistent and excessive use of synthetic pesticides. The interest in creating safer, more sustainable, and ecologically friendly crop protection alternatives has grown as a result of these worries.

As possible substitutes for traditional chemical pesticides, plant-based pesticides—also known as botanical pesticides or biopesticides—have drawn interest. Natural bioactive chemicals found in botanical materials may have insecticidal, antibacterial, antifungal, and other defensive qualities. The development of agricultural products based on renewable biological resources may be made possible by their utilization. Due to its well-known bioactive and insecticidal qualities, neem (Azadirachta indica) is one of the plants being studied for such uses. Neem oil has been studied for its antibacterial and pest-control properties since it contains a number of biologically active chemicals. As part of sustainable crop-protection strategies, the use of neem-based products in agriculture has so drawn a lot of interest.

Another plant resource that has drawn attention is pongamia (Pongamia pinnata), which possesses biological qualities and the ability to produce oil. Pongamia seed oil can be used for a variety of purposes as a renewable plant-based resource. A number of variables, including the extraction technique, equipment, seed quality, seed supply, and other production conditions, might affect the availability and quality of pongamia oil. Therefore, the availability and acquisition of raw resources must also be taken into account when using Pongamia oil in an agricultural product. Pongamia oil and neem oil can be combined to create a plant-based product that uses two renewable oil sources.

Therefore, the creation of neem and Pongamia oil nano emulsions offers a possible method for creating a plant-based formulation for use in agriculture. Neem and Pongamia oils were utilized to create a nano emulsion formulation in the previous experimental work that served as the basis for this investigation. To create a stable and uniform emulsion, the formulation process required the use of appropriate surfactants and co-surfactants. Analytical methods such dynamic light scattering, scanning electron microscopy, Fourier transform infrared spectroscopy, X-ray diffraction, and UV-visible spectroscopy were used to assess the formulation's physicochemical properties. Particle or droplet size, morphology, chemical interactions, structural features, and other formulation parameters are all covered by these characterization techniques.

Antimicrobial and plant-based observations were also used to examine the formulation's biological performance. A disc diffusion assay was used to assess the nano emulsion's antibacterial efficacy against Staphylococcus aureus and Escherichia coli. The nano emulsion showed improved antibacterial activity when compared to pure neem oil, and the formulation created inhibition zones of 18 mm against E. coli and 21 mm against S. aureus. Plant observations at various intervals were also used to assess the formulation. During the observation period, there was a decrease in pest infestation, and there were no obvious indications of phytotoxicity in the treated plants. These results offer an experimental basis for thinking about the formulation as a possible plant-based crop-protection solution.

2. REVIEW OF LITERATURE

2.1 Technology of Nano emulsions:

Oil and water dispersions stabilized by surfactants and co-surfactants are known as nano emulsions. Better dispersion and surface area are provided by their tiny droplet size. They can enhance the availability and delivery of plant chemicals that are poorly soluble in water. Nano emulsions are beneficial for agricultural formulations because of their characteristics.

2.2 The Bioactive Properties of Neem Oil:

Neem seeds or kernels are the primary source of neem (Azadirachta indica) oil. It has bioactive substances such salannin, nimbin, and azadirachtin. These substances have antibacterial, antifungal, and insecticidal properties. As a result, neem is being researched extensively for use in sustainable agriculture.

2.3 The Antimicrobial Qualities of Neem Oil:

There are substances in neem oil that have antibacterial properties. Research has documented action against bacteria such as S. aureus, Pseudomonas, Salmonella, and E. coli. The action may cause cellular functions and microbiological structures to be disrupted. These characteristics justify its application in formulations for plant protection.

2.4 Cost-cutting measures:

Cost optimization finds significant costs and ways to cut them without compromising product quality. Selection of suppliers, use of raw materials, energy consumption, batch size, equipment use, and processing losses are some examples of potential areas. Achieving the necessary biological performance at a fair cost of manufacturing is the goal.

2.5 Scale Economies and Efficiency in Production:

Because fixed expenses are spread over more units, production at a higher scale can lower average costs. Scale-up, however, might call for more funding, equipment, storage, and quality-control systems. Thus, it is important to compare various production volumes. After that, the production scale that is most economically viable can be determined.

2.6 Potential for Commercialization:

Biological efficacy, stability, production cost, scalability, legislation, market acceptability, packaging, and distribution all play a role in commercialization. The technological basis for future progress is provided by laboratory data. However, prior to commercialization, operational and financial viability must also be determined.

2.7 Cost Aspects in the Production of Botanical Products

Raw materials, surfactants, extraction, labour, energy, equipment, testing, packaging, transportation, and overheads are all included in the cost of production. Prices for raw materials might change depending on season and availability. The amount of oil needed is also influenced by extraction efficiency. Thus, a thorough cost study is required.

3. OBJECTIVE

- To record the current method of producing neem-Pongamia oil nano emulsion.
- To determine the activities and resources used in manufacturing.
- To calculate the cost of personnel, energy, equipment, and raw materials.
- To include testing and quality control costs in product pricing.
- To calculate the price per liter of production.
- To calculate appropriate selling prices and margins for contributions.
- To determine the production volume needed to break even.
- To assess various production scales and economies of scale.
- To determine the main causes of costs and areas where they can be cut
- To do critical cost variable sensitivity analysis.
- To evaluate commercial production's potential financial viability.

Table -1: Production Resource Table

Activity	Resource	Quanti ty	Cost basis
Neem oil	Neem oil	50 ml	₹400/L Planning rate
Pongamia oil	Karanja/Pongamia oil	50 ml	₹215/L bulk reference

Tween 80	Polysorbate	25 ml	₹7,393/kg lab-grade reference
PEG 400	PEG 400	25 ml	₹120/kg industrial reference
Water	Distilled water	900 ml	₹5/L assumption
Mixing	Stirrer/homogenizer	1 batch	₹Equipment cost
Labour	Operator	1 hour	₹60/hour assumption
Packaging	1-L container + label	1 unit	₹35 assumption
Quality control	Basic testing allocation	1 batch	₹75 assumption
Overhead	Utilities/admin/wastage	1 batch	₹25 assumption

Table -2: Characterization and quality control Table

Parameter	Existing result	Business relevance
DLS mean droplet size	65 ± 5 nm	Confirms nanoscale formulation
PDI	0.12	Indicates relatively uniform distribution
Stability	30 days reported	Supports formulation stability
SEM	Spherical droplets	Supports morphology
Aggregation	Not observed	Supports physically uniformity
UV-Vis	Peak at 214 nm	Supports bioactive-component monitoring
E coli inhibition	18 mm	Demonstrates biological activity
S.aureus inhibition	21 mm	Demonstrates biological activity
Plant observation	Reduced pest infestation	Preliminary agriculture potential

4. Direct Labour Cost

Direct Labour Cost = Labour Hours × Labour Rate

Therefore:

1 hour × ₹60 = ₹60 per liter

Formula:

Annual Depreciation = (Purchase Price − Salvage Value) ÷ Useful Life

5. Testing Cost

For the existing model, an allocation of ₹75 per saleable litre is used for quality-control and testing expenditure. This value can be reduced greatly when testing expenditures are split over bigger manufacturing batches.

Table -3: Total Estimated cost per liter Table

Cost component	₹/L
Neem oil	20.00
Pongamia oil	10.75
Tween 80	184.83
PEG 400	3.00
Water	4.50
Direct labour	60.00
Energy	10.50
Equipment/depreciation	20.00
Packaging	35.00
QC/testing allocation	75.00
Overhead/wastage	25.00
Estimated total cost	**₹448.58/L**

Profit Margin

Assuming a total production cost of around ₹448.58/L and selling price of ₹750/L:

Profit = ₹750 − ₹448.58

Estimated profit = ₹301.42/L

Margin of Profit = ₹301.42 ÷ ₹750 × 100

Estimated profit margin = 40.19%

Study of Break-Even

Assume ₹3,00,000 in fixed costs per year for the initial model.

The equation

Fixed Cost ÷ Contribution per liter is the break-even quantity.

BEP is equal to ₹3,00,000 ÷ ₹326.42

919 liters annually is the break-even volume.

Therefore, at a selling price of ₹750/L, it would take around 919 salable liters annually to recover the projected fixed cost.

Table -4: Break Even Table

Selling price	Contribution/L	Break even volume
₹600	₹176.42	1700 L
₹650	₹226.42	1325 L

₹700	₹276.42	1085 L
₹750	₹326.42	919 L
₹800	₹376.42	797 L
₹850	₹426.42	704 L

Table -5: Selling price Sensitivity Table

Selling Price	**Profit/L before fixed cost allocation**
₹600	₹151.42
₹650	₹201.42
₹700	₹251.42
₹750	₹301.42
₹800	₹351.42
₹850	₹401.42

The analysis indicates that selling price directly affects profitability. However, a commercial decision should not be made based on the highest price that can be achieved to maximize margin, but also farmer affordability, competing products, dealer margins and perceived product value should be taken into consideration.

6. OPERATIONAL ANALYSIS

10.1 Process Flow:

Procurement

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Cleaning

↓

Drying

↓

Dehulling

↓

Oil Extraction

↓

Filtration

↓

Oil Blending

↓

Surfactant/PEG Addition

↓

Emulsification

↓

Quality Control

↓

Packaging

↓

Storage

↓

Distribution

7. RESULTS AND DISCUSSION

The technical results of the original research provide evidence that the formulation can be prepared as a nano-scale dispersion. DLS analysis showed a mean droplet size of 65±5 nm with PDI of 0.12 and SEM showed spherical droplets with no observable aggregation.

The biological data also point to preliminary activity. The formulation exhibited inhibition zones of 18 mm against E. coli and 21 mm against S. aureus, while plant observations showed reduced pest infestation with no visible phytotoxic effects during the observed period.

From MBA's perspective, the financial model estimates a preliminary production cost of approximately ₹449/L under the stated assumptions. At an indicative selling price of ₹750/L, the model estimates a gross operating surplus of around ₹301/L before fixed annual expenses, taxes and financing costs.

The break-even calculation shows that to recover assumed fixed costs of ₹3 lakh at the ₹750/L selling price, approximately 919 L/year would need to be sold. This implies that the product may become economically attractive at relatively low production volumes if the assumed input costs and selling price can be achieved.

The sensitivity analysis shows that Tween 80 is a significant cost driver under the current assumption of laboratory-grade pricing. So the most cost-effective optimization opportunity will probably be bulk procurement, proper sourcing and formulation optimization at an industrial/agricultural level instead of just reducing electricity consumption.

8. CONCLUSION

The present study is an extension of earlier science development of neem–Pongamia oil nano emulsion into financial and business analysis orientated toward MBA. The initial formulation exhibited nanoscale characteristics, stability, and biological activity, which laid a technical basis for further commercial investigation.

Based on the assumptions provided, the financial model estimates a preliminary production cost of approximately ₹448.58 per litre. Indicative selling price of ₹750 per litre indicates potentially attractive contribution and operating margin.

The break-even analysis indicates that the fixed-cost structure would need approximately 919 litres per year. The sensitivity analysis suggests that the formulation ingredients, particularly Tween 80 at laboratory grade pricing, can have a significant impact on the overall cost.

To conclude, neem–Pongamia nano emulsion has potential commercial and financial feasibility, however, commercialization must be preceded by supplier validation, pilot scale manufacturing, regulatory assessment, extended stability testing and large scale field evaluation. The main managerial opportunity is in the reduction of the costs of formulation and testing, maintaining the technical quality of the original research

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