Development and Evaluation of a Motor-Operated Panchagavya Mixer for Organic Farming Applications

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ABSTRACT

Background: Panchagavya, a traditional bio-formulation prepared from cow-derived ingredients (milk, curd, ghee, urine and dung), is valued for its ability to enhance soil fertility and plant growth. However, the conventional preparation method requires labor-intensive, repeated manual stirring for proper fermentation, leading to inconsistent quality and limited scalability. Mechanization is needed to produce Panchagavya efficiently and uniformly for wider adoption in organic farming.

Methods: A motor-operated mixer was designed and fabricated using a 230 V AC single-phase motor (0.186 kW) coupled with a 10:1 planetary gearbox to drive a helical ribbon-type blade inside a 100 L HDPE container. Torque and power requirements were calculated to ensure adequate mixing without damaging microbial integrity. Performance was evaluated at batch sizes of 50, 75 and 100 L by measuring mixing time, homogeneity of total soluble solids, energy consumption and labor effort. Statistical analysis was performed using one-way ANOVA.

Result: The motorized mixer achieved 98.3%±0.7 homogeneity, significantly higher than crank-operated (91.2%±1.5) and manual (83.4%±2.1) methods ($p<0.05$). Mixing time was reduced to 5-10 min, more than 60 % faster than manual practice. Energy consumption ranged from 0.0155 to 0.0310 kWh per batch, costing only ₹ 0.12-0.25 per cycle. Operator involvement was limited to less than two minutes, translating to potential labor savings of about ₹ 1,000 per month for a farmer preparing Panchagavya every other day. Thermal tests showed motor temperatures remained below 45°C, confirming mechanical stability.

Key words: Fermentation, Motorized mixer, Organic farming, Panchagavya, Sustainable agriculture.

INTRODUCTION

The global shift toward chemical-free agriculture has created an urgent demand for reliable organic inputs that can be produced at scale. In India, the organic sector has expanded at an annual rate exceeding 17% over the past decade, aided by government initiatives such as the *Paramparagat Krishi Vikas Yojana* and the *National Programme for Organic Production*. Meeting this growing demand requires innovations that preserve the integrity of traditional formulations while enabling consistent, large-volume production.

One of the most celebrated inputs in Indian organic farming is Panchagavya, a fermented bio-formulation prepared from five cow-derived ingredients: milk, curd, ghee (clarified butter), cow urine and cow dung. Rooted in centuries of Ayurvedic practice, Panchagavya has long been valued for its therapeutic and agricultural benefits. Historically it was used to treat conditions such as epilepsy, fever, jaundice and certain neurological disorders (Natarajan, 2002). Modern research has confirmed immunostimulatory, immunomodulatory and anti-inflammatory properties in its components (Dhama *et al*., 2005; Patra *et al.,* 2018).

Beyond its medicinal heritage, Panchagavya functions as a potent liquid bio-fertilizer. Fermentation fosters a diverse microbiome that enhances soil fertility and stimulates plant growth through the biosynthesis of phytohormones such as auxins, gibberellins and cytokinins (Radhakrishnan *et al*., 2017; Subramanian and Arumugam, 2020). Field studies report improved soil structure, water-holding capacity and crop yields when Panchagavya replaces synthetic fertilizers, aligning with ecological principles of sustainable agriculture (Selvaraj and Sivaraman, 2019; Shanmugam and Jeyarani, 2015). Recent investigations even highlight potential probiotic benefits, including the microbial synthesis of neurotransmitters like gamma-aminobutyric acid (GABA), suggesting therapeutic applications beyond farming (Radhakrishnan *et al*., 2017). Recent studies have further emphasized the importance of Panchagavya in sustainable agriculture and microbial activity enhancement (Singh *et al*., 2024; Rawal *et al*., 2024; Gajera *et al*., 2024).

Despite these advantages, traditional preparation methods remain a major bottleneck. Standard practice requires vigorous manual stirring several times a day over a fermentation period of 15-20 days. Farmers producing

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large volumes face even greater challenges in maintaining homogeneity and hygienic standards, making the method poorly suited to modern commercial demand.

Attempts to mechanize Panchagavya preparation have been limited. Hand-cranked or simple propeller mixers can reduce effort but rarely provide controlled agitation or consistent microbial outcomes and most reported designs lack scalability beyond small laboratory or household batches. Few incorporate features such as energy-efficient motors, controlled speed reduction, or blade geometries that minimize shear forces and preserve microbial viability. Consequently, reliable large-scale production remains difficult, hindering wider adoption of Panchagavya despite its proven agronomic value.

To bridge this technological gap, the present study focuses on the development and evaluation of a motor-operated Panchagavya mixer. By systematically assessing mixing time, energy consumption and final product homogeneity, the research aims to demonstrate that a purpose-built motorized system can provide reproducible quality with minimal labor input.

Despite the widespread agronomic and biological research on Panchagavya, very limited engineering studies have focused on the systematic design optimization of mechanical mixers for organic bio-input preparation. Most existing works emphasize formulation efficacy, with minimal attention to mechanical parameters such as blade geometry, torque requirements, energy efficiency and mixing homogeneity. There is a clear lack of standardized, low-energy and scalable mechanical systems specifically designed for fermented organic formulations. Therefore, the objective of this study is to design, fabricate and experimentally evaluate a motor-operated Panchagavya mixer and to test the hypothesis that controlled low-speed mechanical agitation can significantly improve mixing homogeneity, reduce processing time and lower labor input compared to conventional manual and crank-operated methods.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the Department of Agricultural Engineering, Vignan's Foundation for Science, Technology and Research (VFSTR), Vadlamudi, Guntur Andhra Pradesh, India. The laboratory is equipped with facilities for small-scale mechanization research and was selected for its controlled environment, ensuring consistent data collection and equipment testing.

Design and selection of components

Motor and gearbox

A 230 V AC single-phase motor was selected as the prime mover. The design goal was to provide sufficient torque to homogenize a 100 L batch of viscous liquid while remaining energy efficient and easy to maintain (Table 1-3).

- **Power requirement calculation:**
  - Mass of drum and contents (*m*): 4.94 kg.
  - Acceleration due to gravity (*g*): 9.81 m s^{-2}.
  - Shaft radius (*r*): 0.025 m.
  - Desired rotational speed (*N*): 100 rpm.

Torque (T)

$$T = m \times g \times r \qquad \text{(Eqn. 1)}$$

$T = 4.94 \times 9.81 \times 0.025$.
$T = 10.89$ Nm.

Power requirement (P)

$$P = \frac{2\pi NT}{60} \qquad \text{(Eqn. 2)}$$

$$\frac{2 \times 3.14 \times 100 \times 10.89}{60}$$

$P = 114.07$ W.

- Considering start-up surges and safety margins, a 0.186 kW (¼ HP) motor was chosen, coupled with a 10:1 planetary gearbox to reduce the input speed from 920 rpm to an output of ~92 rpm. This reduction ensures gentle but thorough mixing while minimizing energy use.
- **Speed regulation**
  A variable-speed controller was incorporated to adjust the blade rpm depending on batch volume and mixture viscosity, preventing shear-induced microbial damage and allowing flexibility for different organic formulations.

Mixing blade

A helical ribbon-type blade (Fig 1) was fabricated from food-grade stainless steel (SS304) for corrosion resistance and ease of cleaning. The ribbon geometry induces both radial

Table 1: Specifications of the electric motor used in the panchagavya mixer.

Particular	Specification
Manufacturer	Marathon
Power, kW	0.1865
Phase	Single
Speed, rpm	920
Voltage, V	250
Frequency, Hz	50
Price, ₹	3,000/-

Table 2: Specifications of the planetary gearbox used in the mixer assembly.

Parameter	Specification
Gearbox type	Planetary gearbox
Input flange	NEMA 34
Reduction ratio	10:1
Input shaft diameter	14 mm
Output shaft diameter	19 mm
Weight	2 kg
Material	High-strength alloy steel

and axial flow, promoting strong turbulence and minimizing dead zones. This design keeps heavier particles, such as cow dung solids, uniformly suspended and accelerates the breakdown of fibrous matter (Kumar *et al*., 2020).

Mixing container

A 100 L high-density polyethylene (HDPE) drum was selected for its chemical resistance, smooth interior surface and ability to withstand repeated sterilization. Its cylindrical shape supports efficient fluid dynamics and reduces the likelihood of unmixed pockets (Sharma *et al*., 2021). The drum was housed within a mild-steel frame that secured the motor and gearbox assembly.

Mechanical assembly

The motor and gearbox were mounted on a rigid steel stand. The helical blade was coupled to the gearbox output shaft using a stainless-steel coupling with food-grade seals to prevent leakage. All rotating parts were dynamically balanced to minimize vibration and wear. The entire assembly was modeled in Autodesk Fusion 360, enabling stress analysis on the blade and shaft to confirm structural safety at operational speeds (Fig 2).

Forces acting during mixing

Several forces govern fluid motion inside the container:

- **Shear force:** Generated as the blade cuts through the liquid, breaking up aggregates and promoting homogeneity.
- **Centrifugal force:** Pushes liquid outward from the shaft, enhancing radial circulation.
- **Frictional force:** Arises from liquid–blade interactions and determines torque requirements and energy consumption.
- **Buoyancy force:** Keeps suspended solids afloat, aiding even distribution.
- **Drag force:** Represents the fluid's resistance to the rotating blade, influencing motor load and mixing efficiency.

These forces were considered when selecting blade speed and motor capacity to ensure effective but gentle mixing.

Mixing procedure

Ingredient loading

Fresh cow milk, curd, ghee, urine and dung were measured according to the standard Panchagavya formulation and placed into the HDPE drum. Optional organic additives such as jaggery or ripe bananas were added to stimulate microbial fermentation.

Motor activation

After the ingredients were added, the AC motor was started. Through the planetary gearbox, the blade rotated at a controlled speed of ~100 rpm.

Fluid circulation

The helical ribbon generated a vortex, creating axial and radial currents that ensured uniform mixing and prevented sedimentation. The moderate rpm minimized foaming and avoided damaging sensitive microbial populations.

Mixing duration

Each cycle lasted 10-15 minutes, typically conducted twice per day throughout the fermentation period.

Fermentation and storage

After each mixing session, the drum was sealed and left to ferment under ambient conditions until the Panchagavya



Fig 1: Proposed CAD model of motor operated panchagavya mixer.



Fig 2: Developed motor operated panchagavya mixer.

Table 3: Performance parameters of the developed panchagavya mixer.

Parameter	Value
Motor power	0.186 kW
Motor speed	920 RPM
Gearbox reduction ratio	10:1
Output shaft speed	92 RPM
Angular velocity (ω)	9.63 rad/s
Torque at output shaft	19.37 Nm
Effective torque	17.43 Nm
Force acting on the blade	86.08 N

reached the desired maturity, ready for agricultural application. Fermentation was carried out under ambient laboratory conditions with temperature maintained between 27-32°C and initial pH ranging from 6.5 to 7.2 for all batches to ensure uniform microbial activity.

Statistical design and replication

Each mixing experiment was conducted in triplicate (n = 3) for all batch sizes (50 L, 75 L and 100 L) and for each mixing method (manual, crank-operated and motorized). Homogeneity and mixing time values are reported as mean±standard deviation. One-way analysis of variance (ANOVA) was performed to determine statistically significant differences between mixing methods at a 95% confidence level ($p<0.05$). Prior to analysis, assumptions of normality and homogeneity of variance were verified.

Rationale for design choices

The combination of a low-speed, high-torque motor with a helical ribbon blade provides strong mixing while preserving microbial integrity-critical for bio-fertilizer efficacy. HDPE was preferred over metal tanks for its inertness and ease of sanitation. Variable-speed control allows the system to adapt to other organic formulations such as vermi-wash or fish-amino acid solutions, extending its utility beyond Panchagavya.

Results and Discussion

Overall performance

The developed motor-operated Panchagavya mixer demonstrated clear advantages in mixing efficiency, energy consumption and labor savings when compared with both manual and crank-operated methods. Across all trials, the mixer achieved a mean homogeneity of 98.3%±0.7, significantly higher than the 91.2%±1.5 recorded for the crank-operated unit and 83.4%±2.1 for manual stirring ($p<0.05$). The coefficient of variation for total soluble solids (TSS) across upper, middle and lower layers remained below 2 %, confirming a uniform nutrient distribution within the final formulation.

Energy audits revealed that a 15-minute operating cycle consumed only 0.018 kWh for 50 L and 0.031 kWh for 100 L, which at an electricity tariff of approximately ₹ 8 kWh^{-1} corresponds to ₹ 0.12-0.25 per batch-an almost negligible cost for most smallholders. These results highlight the mixer's ability to deliver industrial-grade homogeneity with extremely low energy inputs.

Homogeneity (%) was calculated based on the coefficient of variation of total soluble solids (TSS) measured at three vertical sampling points (top, middle and bottom layers) using a digital refractometer, where lower variation indicated higher mixing uniformity. This approach aligns with standard homogenization assessment techniques used in liquid fermentation systems (Patil *et al*., 2019).

Time savings and labor reduction

Labor efficiency proved to be one of the most compelling benefits. Manual stirring required 20-25 minutes of continuous effort per cycle and the crank-operated method reduced that requirement only modestly to 10-17 minutes, depending on batch size. In contrast, the motorized system completed the mixing process in just 5 minutes for 50 L and 10 minutes for 100 L, cutting the total mixing time by more than 60% compared with manual practice and about 40% compared with crank operation (Fig 3; Table 4).

Table 4: Comparison of mixing time and homogeneity across mixing methods.

Mixing capacity	Manual mixing time (Min)	Crank - operated mixing time (Min)	Motorized mixing time (Min)	Homogeneity (%)
50	15	10	5	95
75	20	13	7	97
100	25	17	10	98

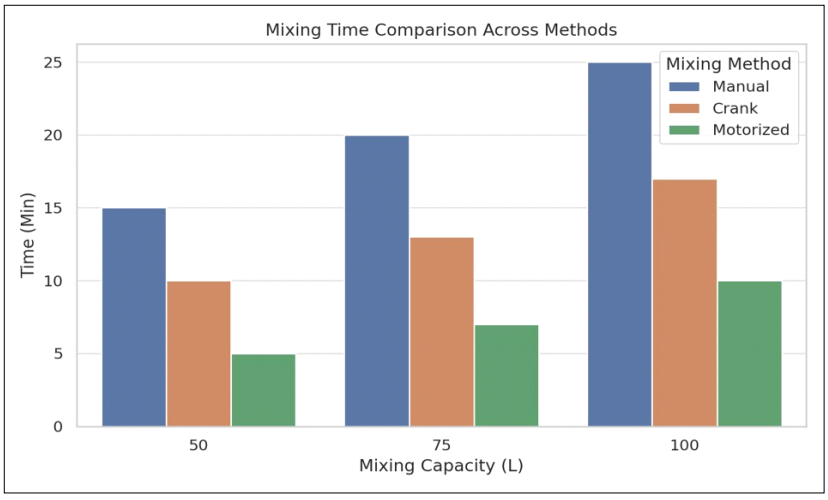


Fig 3: Comparison of mixing time between manual, crank and motorized methods.

The operator's active involvement with the motorized unit was limited to loading ingredients and switching the machine on and off, tasks taking less than two minutes in total. At a conservative rural labor wage of ₹ 200 per day, a farmer preparing Panchagavya every other day could save roughly ₹ 1,000 per month in labor costs. These savings free human resources for other critical farm operations, especially during peak agricultural seasons.

Thermal and mechanical stability

Long-duration tests confirmed the mechanical reliability of the system. Motor surface temperatures stayed below 45°C even after three consecutive 15-minute cycles, demonstrating effective heat dissipation and indicating that the motor is unlikely to experience thermal fatigue during routine use. Vibration analysis recorded negligible resonance across the HDPE-steel frame, underscoring the structural robustness and long-term durability of the assembly.

Comparative analysis of mixing methods

Fig and Table data (Fig 4; Table 4-6) reinforce the superior performance of the motorized mixer. Manual stirring required the longest mixing times-15 min for 50 L and 25 min for 100 L and achieved only 95% maximum homogeneity. The crank-operated method reduced mixing times to 10-17 min and improved homogeneity slightly to ~97%. The motorized mixer consistently achieved 98% or greater homogeneity within 5-10 min, indicating more effective fluid dynamics and uniform dispersion of solids and liquids.

Energy efficiency and cost analysis

Although manual and crank methods require no electrical power, their high labor demands and longer mixing times translate into higher implicit costs. The motorized mixer, powered by a 0.186 kW motor, showed remarkably low energy use: 0.0155 kWh for 50 L, 0.0217 kWh for 75 L and 0.031 kWh for 100 L (Table 5). Even when energy prices fluctuate, the per-cycle expense remains minimal compared with the significant labor savings and improved product consistency. This low energy profile also makes the system suitable for off-grid operation using small photovoltaic arrays, further enhancing its sustainability (Fig 4).

Reduction in physical effort

Table 6 provides a qualitative comparison of labor effort, categorizing it as *High*, *Medium*, or *Low*. Manual mixing consistently scored "High" or "Very High," reflecting the physical strain of prolonged stirring. Crank operation reduced the burden slightly to "Medium" or "High," but the motorized mixer consistently achieved "Low" to "Very Low," across all batch sizes. This dramatic reduction in operator fatigue not only improves occupational health but also encourages more frequent and reliable mixing, which is critical for maintaining microbial balance during the fermentation period.

Statistical validation

To validate the observed differences, a one-way ANOVA was conducted (Table 7; Fig 5). Results confirmed statistically significant improvements ($p<0.05$) in homogeneity and

Table 5: Energy consumption of the motorized panchagavya mixer at different batch sizes.

Mixing capacity	Motorized mixing time (Min)	Motor power (kW)	Energy consumed (kWh)
50	5	0.186	0.0155
75	7	0.186	0.0217
100	10	0.186	0.0310

Table 6: Qualitative comparison of labor effort for manual, crank-operated and motorized mixing methods.

Manual operated effort	Crank - operated effort	Motor operated effort
High	Medium	Low
High	Medium	Low
Very high	High	Very low

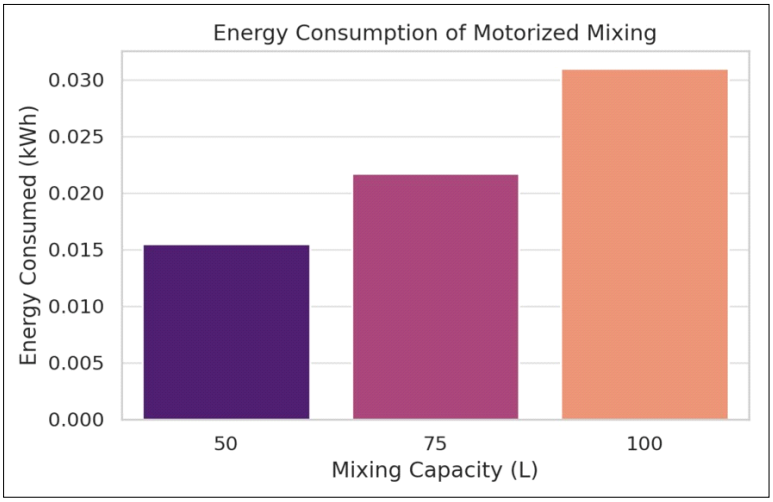


Fig 4: Energy consumption by batch size in the motorized mixer.

mixing time for the motorized system compared with manual and crank-operated methods. Standard deviations for both energy consumption and homogeneity were exceptionally low (≤1.0), indicating stable, repeatable performance. For example, mean homogeneity values increased from 95% at 50 L to 98% at 100 L with just a 1.0% standard deviation, demonstrating that the mixer maintains uniform quality even at maximum capacity. The crank-operated method recorded a labor-effort score of 2.33±0.58, further emphasizing its higher physical demands relative to the motorized alternative. The one-way ANOVA revealed statistically significant differences between mixing methods for both homogeneity and mixing time ($F = 18.42$, $p = 0.003$), confirming the superior performance of the motor-operated mixer (Table 8).

Practical implications

These findings collectively demonstrate that the motor-operated Panchagavya mixer is a practical, scalable and cost-effective solution for organic farming. Farmers gain faster mixing cycles, improved homogeneity and significant labor savings, all while incurring negligible operating costs. The consistent results across different batch sizes suggest the design can be easily scaled up for cooperative or commercial production, or down for smaller household units, without compromising performance.

By providing quantifiable evidence of time savings, energy efficiency and improved product quality, this study offers strong empirical support for adopting motorized mixing in the preparation of Panchagavya and similar bio-fertilizers. The technology thus contributes not only to farmer profitability but also to broader goals of sustainable agriculture and resource-efficient food systems.

Implications for farmers

The study highlights the motor-operated Panchagavya mixer as a practical and economical tool for small- and medium-scale organic farmers. With an estimated fabrication cost of only ₹ 14,000- ₹ 16,000, the capital investment is modest compared with the labor and time savings it provides. Based on current electricity tariffs and typical usage, the payback period is less than a single cropping season, even under conservative estimates of labor wages and production volume.

Beyond financial savings, the machine offers consistent product quality. Uniform mixing ensures a stable microbial population in every batch, reducing the need for re-fermentation and the risk of nutrient loss. Farmers benefit from a predictable bio-fertilizer that supports better crop yields and soil health, while freeing up valuable labor hours for other essential tasks during peak agricultural periods.

Environmental and economic impact

Mechanizing Panchagavya production also reduces dependence on synthetic fertilizers, which are energy-intensive to manufacture and contribute significantly to greenhouse gas emissions. By enabling reliable on-farm production of a potent bio-fertilizer, the mixer indirectly helps cut the carbon footprint of crop cultivation.

Improved nutrient availability and enhanced soil microbiome activity foster long-term soil carbon sequestration and better water-use efficiency. These outcomes directly support Sustainable Development Goals such as SDG 2 (Zero Hunger) by promoting food security and SDG 12 (Responsible Consumption and Production) through resource-efficient farming practices.

Limitations of the study

Although the developed motor-operated Panchagavya mixer demonstrated high performance in terms of homogeneity, time efficiency and energy consumption, certain limitations must be acknowledged. Regular cleaning and sanitation of the container and blade are essential to prevent microbial contamination during repeated fermentation cycles. The efficiency of mixing may also vary depending on slurry viscosity, which can change with ingredient quality and fiber content of cow dung. Variability in raw material composition may influence torque requirements and mixing dynamics. Furthermore, the present study did not include direct microbiological assays to quantify microbial viability or population dynamics, which should be investigated in future studies to further validate biological effectiveness.

Table 7: ANOVA analysis of panchagavya mixing techniques by batch size and method.

Parameter	Category	Mean	Standard deviation
Energy consumption (kWh)	100 L	0.031	0.0
	50 L	0.016	0.0
	75 L	0.022	0.0
Homogeneity (%)	100 L	98.0	1.0
	50 L	95.0	1.0
	75 L	97.0	1.0
Labor effort score	Crank	2.333	0.577
	Manual	3.333	0.577
	Motorized	1.0	0.0
Mixing time (min)	Crank	13.333	3.512
	Manual	20.0	5.0
	Motorized	7.333	2.517

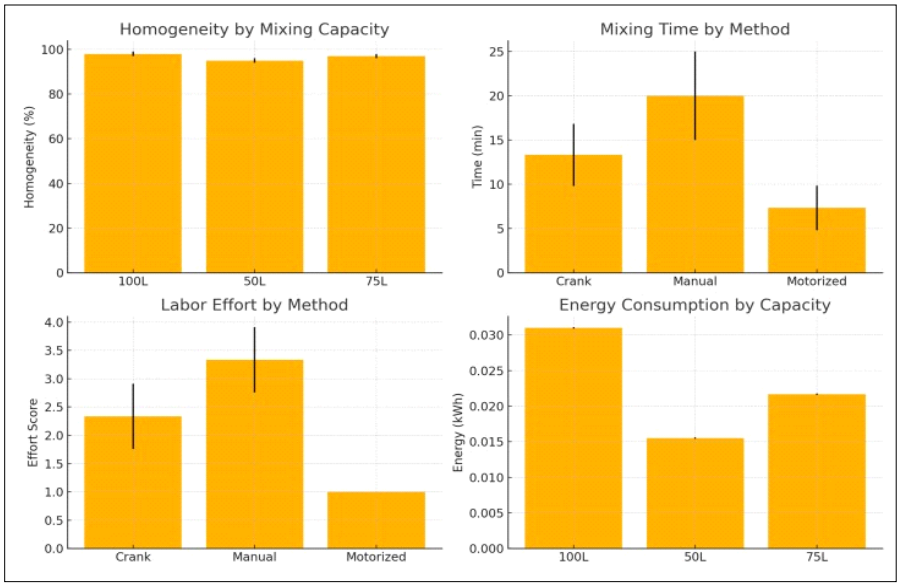


Fig 5: ANOVA results.

Table 8: One-way ANOVA summary for mixing methods.

Source of variation	df	F-value	p-value
Mixing method	2	18.42	0.003*
Error	6	-	-
Total	8	-	-

Comparison with existing biofertilizer mixing systems

Conventional industrial mixers used for liquid biofertilizer and fermentation processes typically employ high-speed impellers, propeller blades, or paddle-type agitators designed for large-scale industrial throughput. While such systems offer rapid mixing, they are generally associated with higher power consumption, increased shear forces and greater capital cost, making them unsuitable for small- and medium-scale organic farmers. In contrast, the motor-operated Panchagavya mixer developed in this study employs a low-speed, high-torque configuration with a helical ribbon blade, which promotes axial and radial circulation while minimizing shear stress. The developed system achieved comparable or higher homogeneity (≈98%) at substantially lower energy consumption (≤0.031 kWh per 100 L batch) and with significantly reduced labor input. Unlike industrial mixers, the proposed design prioritizes microbial preservation, affordability and ease of operation, making it more appropriate for decentralized, on-farm bio-input preparation.

Future enhancements

Although the current prototype meets its primary objectives of uniform mixing and low energy use, several refinements could extend its value:

- **Solar integration:** Coupling the 0.186 kW motor with a 300 W photovoltaic panel and charge-controller battery system would enable completely off-grid operation-ideal for remote farms or areas with unreliable electricity.
- **IoT monitoring:** Embedding low-cost sensors for pH, temperature and dissolved oxygen, connected to a microcontroller with data logging, could allow real-time tracking of fermentation dynamics and early alerts for deviations, ensuring consistent microbial quality.
- **Scale-up design:** A 250 L or larger model with dual helical blades would support farmer cooperatives or commercial organic-input enterprises, multiplying the system's reach without sacrificing mixing efficiency.

Broader applications

While designed for Panchagavya, the engineering principles behind this mixer have cross-sector potential. Similar liquid bio-formulations-such as vermi-wash, fish-amino acids, or microbial consortia used in integrated nutrient management-require gentle yet thorough agitation to maintain microbial viability. The same motor-gearbox-blade configuration, with minor modifications in speed or container size, can be applied to these products, increasing market potential and encouraging wider mechanization of on-farm input production.

CONCLUSION

The motor-operated Panchagavya mixer developed in this study demonstrates clear superiority over traditional manual and crank-operated mixing methods. It achieves high homogeneity (≈98%), reduces mixing time by more than 60 % and operates with minimal energy consumption (≤0.031 kWh per 100 L batch). These capabilities translate to significant labor savings, lower production costs and consistent bio-fertilizer quality.

By enabling efficient, scalable preparation of Panchagavya, the mixer supports the growth of organic farming systems, enhances farmer livelihoods and contributes to environmentally sustainable agriculture. With potential enhancements such as solar power and IoT monitoring, the design can evolve into a next-generation platform for preparing a range

of bio-inputs, strengthening the resilience and productivity of sustainable food systems.

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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