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Review article

Thresher-Dehusker Farm Machinery: Review of current situation and future needs in Indian context and development of prototype unit

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Abstract

Importance of the work: This research work highlighted India's agricultural innovation through mechanization and technology for smallholder farmers, emphasizing the efficiency of agricultural engineering technologies (AETs) and proposing solutions and presenting a case study on finger millet crop equipment development.

Objectives: To evaluate agricultural innovation barriers, propose AET solutions, analyze finger millet crop processing and develop a cost-effective thresher for smallholder farmers.

Materials & Methods: The methodology involved a literature review and product, user and market studies, quality function deployment (QFD)-based concept development, and weighted ranking for selection. Various threshers were categorized based on drum ty pes, such as peg and rasp bar. Evaluation covered rotary and pedal-operated threshers. The QFD matrix guided concept derivation.

Results: The empirical validation outcomes of the designed thresher yield identified numerical findings crucial for evaluating its operational efficacy. The machine had a threshing efficiency in the range 60–70%, reflecting its capacity to effectively separate finger millet from dry ear buds. This critical performance metric emphasized the machine's proficiency in agricultural processing. Furthermore, the derived yield indicated a conversion ratio of 0.5 kg finger millet/kg dry ear buds, quantifying the effectiveness of the thresher in the context of crop output. Additionally, the stipulated duration of 10 min for threshing 1 kg of finger millet underscored the temporal aspects of the machine's operational cycle, while its reported capacity of 6–7 kg/hr delineated its throughput capability. These quantitative parameters substantiated the pragmatic utility and efficacy of the designed thresher within the agricultural milieu, fostering a nuanced understanding of its quantitative performance metrics.

Main finding: The central discovery emphasized the thresher's major operational efficiency (60–70%) and a notable conversion ratio (0.5 kg finger millet/kg ear buds). This pivotal outcome underscored the research's contribution to advancing agricultural mechanization, particularly benefitting smallholder farmers.

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Introduction

Agriculture, a blend of art and science, encompasses vital pre- and post-agricultural processes for food and raw material production. Despite engaging 36% of the global workforce, it contributes only 3% to the world's gross domestic product (GDP), as highlighted by World Bank data (World Health Organization, 2022). In India, one-half of the workforce is involved in agriculture, generating 14% of the country's GDP and supporting 60–70% of the population (World Health Organization, 2022), Challenges include labor-intensive processes, farmer migration, and the need for reduced pesticide and fertilizer use on small farms (Ministry of Agriculture, 2022). A diminishing ratio of agricultural-to-total workers has led to a critical farm labor shortage (United Nations Economic and Social Commission for Asia and the Pacific, 2020). Mechanization is crucial to boost production, overcome labor scarcity, and meet demand (Karthikeyan, 2009).

Role of farm mechanization

Farm mechanization plays a vital role in addressing agricultural challenges by optimizing operations through mechanization, mitigating labor scarcity, improving profitability, streamlining processes, and ensuring precision in input placemen. Beyond enhancing labor efficiency and safety, mechanization aids in converting uncultivated land to agricultural land, contributing to a country's economic future (Verma, 2006). Mechanization leads to substantial input savings in seeds (15–20%) and fertilizers (15–20%), while also increasing cropping intensity (5–20%) and overall efficiency. The impact of mechanization on GDP per person in agriculture is evident in countries such as the Republic of Korea, Japan, and the USA. The increasing feminization of the agricultural work force highlights the necessity for gender-specific interventions in farm mechanization (Sanjeev, 2021).

Sustainable development goals

Farm mechanization is crucial for realizing the United Nation's 2030 Agenda for Sustainable Development The objective is to double agricultural productivity and incomes by 2030, particularly for women, indigenous people, and family farmers. Agricultural mechanization stands out as a pivotal factor in achieving sustainable food security and reducing rural poverty, contributing to enhanced yield, quality, and income generation (Clarke, 2000).

Challenges faced by agriculture in India

Since the Green Revolution, India has seen substantial agricultural growth, bolstering food security and reducing poverty (Fan et al., 2008). Despite progress, the sector has fallen short of the targeted 4% growth, grappling with issues of malnutrition and poverty. Past government investments in agricultural research (AR) and development have proven beneficial for India's agricultural sector (Pal et al., 2005). The research community emphasizes addressing concerns such as sustainable resource management, food quality and safety, household food and nutritional security, and poverty reduction.

Agricultural research in India

The research and development (R&D) structure in India encompasses research laboratories, an extensive network of educational centers, and a proficient human resource pool. The Indian research and development (R&D) structure feature research laboratories, an extensive educational network, and a skilled human resource pool. The Indian Agricultural Research (AR) system operates on a national level with 100 institutes overseen by the Indian Council for Agricultural Research (Est., 1929) and on a regional level with State Agricultural Universities (SAUs) tailored for state-specific education delivery. ICAR plays a crucial role in planning and coordinating nationwide agricultural research and education, overseeing 97 agencies (45 institutes, 17 National Research Centres, 25 project directorates, and 6 national bureaus). ICAR supports a network known as Krishi Vigyan Kendra for frontline extension activities (Pal et al., 2012). SAUs manage Krishi Anusandhan Units, with ICAR contributing 10% of the budget, a share that has notably increased recently. With 55 SAUs and 6,158 researchers, these institutions, including 16 identified agricultural universities in India, actively pursue diverse projects to advance agricultural activities.

Proven agricultural engineering technologies for smallholder farmers in India

The technologies have been proven in different areas of farm power and mechanization which also incorporate agro-processing for value addition. In addition, there has been technological development in harnessing renewable energy and water for utilization in various agricultural activities.

Farm tools and implementation

Many tools are used for various farming activities that have been adapted to several local farmlands. The tools are implemented for performing activities, including ploughing, seeding, transplanting, weeding, harvesting, on–farm transportation and many more. The adaptation of these technologies tends to reduce the manual workload in farm operations and has the potential to ensure timely operations.

Review of agricultural universities in India

The following institutes have made major contributions to agricultural technology development, addressing various challenges and optimizing farm operations across different regions of India.

Acharya NG Ranga Agricultural University, Hyderabad:
- Developed low-cost lightweight tractor
- Evaluation of sugarcane varieties adapted to drought situations
- Demonstration of cotton production machinery for improved productivity
- Standardization of sugarcane infestation techniques
- Development of agro-techniques for enhancing water use efficiency in cotton

Tamil Nadu Agricultural University, Coimbatore:
- Designed tractor-operated cassava planter
- Developed fertilizer applicator for paddy transplanter
- Creation of multirow power weeder for narrow-spaced crops
- Evaluated minor millet seeder under different parameters
- Conducted research on integrated farming systems and water harvesting

Indira Gandhi Krishi Vishwavidyalaya, Chhattisgarh:
- Innovated various seed drills and paddy puddler
- Introduced gender-friendly paddy weeder
- Focused on farm mechanization in rainfed agriculture
- Evaluated integrated farming system models for economic viability
- Studied the impact of weed management on crop growth and yield

Jawa harlal Nehru Krishi Vishwavidyalaya, Madhya Pradesh:
- Implemented mega seed project for various crops
- Developed agro-technology for different climatic zones
- Produced high-tech horticulture products
- Designed low-cost threshers and chickpea stripping machines
- Explored techniques for screening crop genotypes against diseases

Junagadh Agricultural University, Gujarat:
- Evaluated agricultural machinery for banana cultivation
- Developed simulation models and pneumatic seeders
- Researched on groundnut salinity responses
- Investigated wind pump-operated drip irrigation for greenhouses
- Evaluated performance of solar greenhouses and agricultural waste shredders

Maharana Pratap University of Agriculture and Technology, Rajasthan:
- Evaluated various cultivators and seed drills
- Developed technology for drying industrial products
- Demonstrated solar tunnel dryers for energy conservation
- Cultivation protocols for mushrooms
- Analyzed farmers' adaptation patterns to new technologies

Navsari Agricultural University, Gujarat:
- Studied castor cultivation under different patterns
- Researched on beneficial cultivation practices for fruits
- Identified Fusarium wilt in bananas and its management
- Investigated various soil characteristics and crop responses

Punjab Agricultural University, Punjab:
- Developed tractor-operated machines and ploughs
- Studied seed properties and absorption behavior
- Optimized groundnut production under resource constraints
- Researched weed control in agri-horticulture systems

Assam Agricultural University, Assam:
- Studied genes contributing to resistance against diseases
- Analyzed marketing strategies for horticultural crops
- Conducted biodiversity studies and preservation methods
- Explored factors affecting fertilizer consumption in the region

Central Agricultural University, Manipur:
- Researched seed priming and soil moisture conservation
- Analyzed microclimatic conditions for maize cultivation
- Developed cost-effective cultivation technologies
- Provided training manuals for paddy cultivation

Advancing agricultural engineering through private sector innovation, utilization, and dissemination

The private sector contribution to agricultural engineering and technology is made up of various segments. The segmentation is segregated into local equipment producers, importers of equipment, suppliers and service, as shown in Table 1

Table 1 Manufacturers and processing equipment and spares

Segment	Nomenclature
Local domestic manufacturers of agricultural mechanization and processing equipment and spares	• Soroti Agricultural Implements and Machinery Manufacturing Co. Ltd, (SAIMMCO) focuses on draught animal power implements and postharvest technologies such as oil presses, rice hullers and nut sellers. • Tonnet Agro Engineering Co. Ltd manufactures an assortment of postharvest handling equipment such as maize mills and hullers, groundnut shellers and paste grinders, seed cleaners for all cereals, cassava chippers and graters, feed mixers and feed mills and forage choppers. • Bora Agro-Technologies Ltd. specializes in the design and manufacture of post-harvest handling equipment
Importers, distributors and dealers in farm machinery equipment and their spares	• Engineering solutions: Massey Ferguson and other agricultural equipment. • Akamba Enterprises: Itemco tractors. • Cooper Motor Corporation: New Holland. • Farm engineering: Sunalika • Agrotec: Mahindra • Wavaholdings: Deutz. • Cars and general: Tafe tractors. • Chinese Machinery Ltd: walking tractors and post-harvest technologies such as wheat & maize milling equipment, rice hullers and juice extractors. • Farm Rite Machineries & Equipment Ltd: New Holland tractors and other agricultural equipment. • JBT engineering works Manufacturing and marketing the motorized maize sheller and the rice thresher. • Agro-machinery and Equipment Manufacturing Company: Manufacturing and marketing the hand-cranked maize sheller among others.
Non-government organizations engaged in agricultural mechanization	• Sasakawa Global 2000 • Soroti Catholic diocese integrated development organization (SOCADIDO). • Verdes Eilanden Country Office East African (VECO EA). • Heifer International. • SNV (Dutch Development Organization)
Lead buyers of advanced agricultural engineering technology	• Nilgiri Tea Plantations, Tamil Nadu. • Jorhat Tea Bungalows, Assam. • Kanan Devan Hills Plantation, Munnar. • Large sugarcane estates, Mysore. • Rice estates of Andhra Pradesh, Tamil Nadu.
Informal sector	• Informal sectors small-scale enterprises and other stakeholders with no formal education or training play a key role in the development of AETs such as rice hullers, fire fuelled ovens, maize mills, coffee de-hullers, maize graders, feed mixers, nut crushers, and chuff cutters.

Constraints for adaptation of agricultural engineering technologies

Despite documented benefits, the adoption of AETs in India has been limited. The primary challenges include the financial constraints faced by small-land-holding farmers who are unable to afford investments in AETs. The high cost of advanced technologies often renders them unused, posing a barrier to promoting food security among farmers. Agriculture, deemed a high-risk venture, struggles to attract development loans, as observed by Bergamo and Romano (2016). Mechanizing small and non-contiguous groups of small farms has been proven economically unviable, particularly in operations such as land preparation and harvesting, given the lack of economies of scale. With the ongoing reduction in average farm size, more farms fall into the adverse category, making individual ownership of agricultural machinery progressively more uneconomical (Lowder, 2016).

To address these challenges, the Department of Agriculture and Farmers Welfare (DA & FW) in India aims to double farmer income by 2022 through a strategy recommended by the Indian Machinery Committee (IMC). However, the DA & FW has identified a shortage of trained machinery operators, mechanics and equipment managers leading to poor equipment repair and maintenance. Farm Machinery Training & Testing Institutes, located at Bundni, Hissar, Garladinne, and Biswanath Chariali, are playing a crucial role in providing training to various beneficiaries, including farmers, technicians, undergraduate engineers, entrepreneurs, and foreign nationals.

Poor linkage between R&D systems, manufacturers, distributors, agencies, and tech developers has resulted in weak commercialization of agricultural mechanization. The Submission of Agricultural Mechanization, introduced by the Department of Agriculture Cooperation and

Farmers' Welfare, aims to catalyze inclusive growth by increasing the reach of farm mechanization to small and marginal farmers and regions with low farm power availability. Effective adoption of advanced technologies necessitates detailed demonstrations for farmers, which the government and various companies recognize as essential for technology uptake.

The inadequacy of services contributes to breakdowns and the instability of machinery and agricultural technologies in rural areas. Establishing fixed and mobile service stations and workshops closer to areas with a high concentration of agricultural machinery is crucial for effective service provision. Land ownership insecurity and limited transportation options further impede farmers' investment in mechanization and AETs. Central sector schemes, such as cluster development, on-farm and off-farm input production, and the establishment of integrated processing units, aim to address these issues and promote economic growth and improved living standards in rural areas. Enhancing rural infrastructure can generate employment opportunities, increase productivity, provide access to basic goods and services, and improve the overall health and well-being of the population in national centre for atmospheric research (Est., 2007).

Future strategies for developing and increasing the adoption of agricultural engineering technologies in India

The future of AETs in India hinges on their interaction with key drivers such as policy, economics, research, social, and institutional partnerships. To ensure widespread adoption, future strategies must prioritize simplicity, cost-effectiveness, and reliability for multiple units. Frontline demonstrations across the country, totaling 250 units, aim to showcase the efficacy of advanced technologies. User-friendly agricultural machinery with low maintenance costs is essential for accessibility, benefiting low-income individuals. The Krishi Yantra Dhare–Farm Machinery Custom Hire Service supports small and marginal farmers by providing high-tech farm machinery at nominal charges. Local machinery incorporation during fabrication helps reduce manufacturing costs, and a gender-sensitive design approach enhances user-friendliness and ergonomics.

Standardization of agricultural engineering technologies

The materials used for manufacturing and production must be standardized for production and enforced by the Bureau of Indian Standard to enable and control quality. There has to be easy access to spares and repairs in an open market. The incorporation of standards will help organize informal sectors for production. Quality testing, operational testing, product verification and test standards are necessary to verify the manufacturer's claims provided in the technical specifications for assessing machine performance under local conditions.

Relevance behind research

This review has identified many of the needs of small-scale and medium-scale farmers during the post-processing steps of threshing and de-husking of finger millet crop cultivation. The aim was develop a low cost compact thresher cum de-husker for a finger millet crop to be used by marginal Indian farmers addressing functional and usability aspects

Materials and Methods

The study applied a comprehensive methodology encompassing a literature review, product study data collection, a user study, and market analysis using tools such as questionnaires and quality function deployment (QFD). This process identifies needs to formulate the target product design specification. Threshers and de-huskers are categorized based on the type of drums used for threshing. Peg-type threshing drums use projected pins on the outer circumference and inner surface, suitable for millet threshing. Rasp bar-type drums feature helical grooves, pressing ear buds against round pins for threshing, with the gap between them crucial for efficiency. Rotary thresher utilizes beater plates and a blower for husk removal. The patented pedal-operated thresher uses stationary and rotary blades with a blower unit for husk separation. The final product design was determined using a weighted ranking method based on the QFD matrix.

Quality function deployment analysis

Fig. 1 depicts the various technical voices of the customer along with their weighted percentage ratings. Fig. 2 provides the design specifications for the thresher.

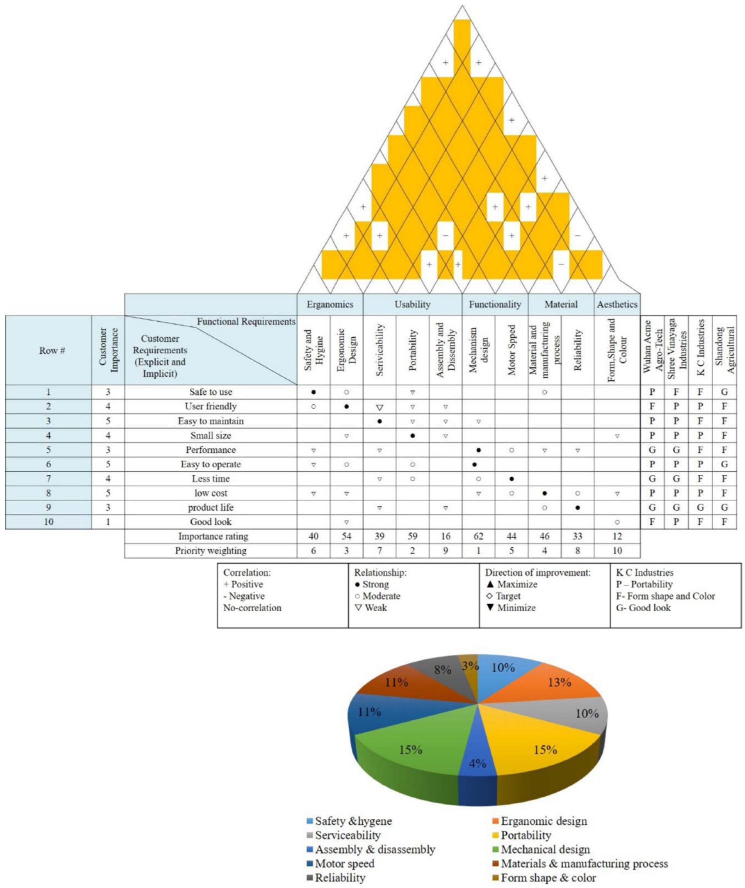

Fig. 1 Quality function deployment analysis, where light-lined circles indicate less weighting (1), rectangles indicate medium weighting (3) and full-line circles indicate more weighting (5)

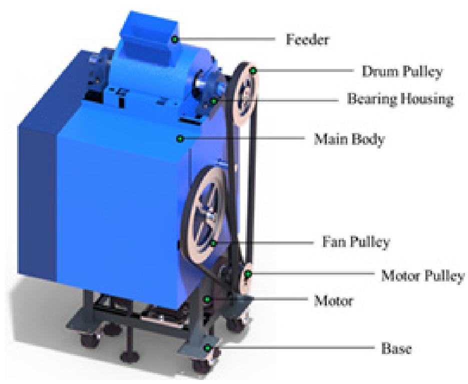

Fig. 2 Thresher cum de-husker

Concept Generations and Selection: The concept is selected by the rating over the selected criteria. Each concept was validated with weights, as shown in Table 3, considering some of the important parameters such as manufacturability, maintenance, performance and cost. Concept 5 was selected for further detailing and developing

Table 2 Design specification of thresher cum de-husker

No.	Factor	Specifications
1	Product Name	Thresher cum de-husker
2	Area of use	Indian village and small-scale farmers
3	Material	Main frame: MS angle, covering - 18GA CRS
4	Size (mm)	910 × 445 × 511
5	Weight (kg)	80
6	Features	Feeder, De-husk fan, Adjustable threshing, Hinge mounted cover
7	Motor	1 HP, Single phase AC
8	Revolutions per minute	1,400
9	Powered by	AC motor
10	Mechanism	Threshing by dimple sheet and slider crank
11	Capacity	2 kg of finger millet/hr
12	Threshing efficiency	80%
13	Cost	USD 180

Table 3 Weighted ranking method

Total score		Concept-1		Concept-2		Concept-3		Concept-4		Concept-5	
											
Criteria	Weighting	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Operation	10%	1	0.1	3	0.3	3	0.3	5	0.5	1	0.1
Maintenance	5%	5	0.25	1	0.5	1	0.05	1	0.05	5	0.25
Size	20%	3	0.6	5	1	5	1	5	1	1	0.2
Performance	25%	1	0.25	5	1.25	3	0.75	5	1.25	3	0.75
Cost	20%	5	1	3	0.6	3	0.6	3	0.6	1	0.2
Safety	5%	1	0.05	1	0.05	5	0.25	5	0.25	1	0.05
Manufacturability	15%	5	0.75	5	0.75	5	0.75	5	0.75	1	0.15
Total score			3		4		3.7		4.4		1.7
Ranking		2		4		3		5		1	
Decision		Discard		Discard		Discard		Discard		Develop	

Major components and final assembly

The thresher cum de-husker machine is shown in Fig. 2. It consists of the: frame assembly, fan assembly-1, fan assembly-2, threshing drum assembly, oscillating tray and cam mechanism. Fan assembly-1 fan is mounted on a shaft and the shaft is connected to the motor via fan pulley-2. Steel sections that were 2.54 cm L-angled were welded to create the frame.

Experimental assessment was conducted in the Form Machinery Unit, University of Agricultural Sciences Dharwad (UASD), Dharwad, Karnataka, India. The validation of the machine was based on different farmers threshing efficiency, with cost and portability being the major parameters considered in the design concept. Hence validation has focused on these components from a group of end users;

Results and Discussion

In summary, 1 kg of dry ear buds generated 0.5 kg of finger millet, with the time taken for threshing 1 kg of finger millet being 10 min, the capacity of the machine was 6–7 kg/hr and the efficiency of the machine was 60 –70%.

AET has the potential to optimize labor usage and enhance efficiency along the value chain, reducing post-harvest losses and adding value to products. Future strategies should focus on adapting increased use of AET, addressing smallholder appropriateness and standardization. Human resource development in AE, through technical skill enhancement, contributes to private sector engagement and economic initiatives. Intellectual property rights enforcement is crucial. Government formalization of agricultural mechanization policies is necessary, including creating a portfolio for AE professionals at local levels. Technical skill development in technology-driven farm operations will improve AE and benefit the nation.

The final fabricated model for threshing Finger Millet grain considered key parameters such as threshing efficiency, cost, and portability. Validation was conducted with end users, with threshing 1 kg of dry ear buds producing 0.5 kg of Finger Millet, indicating a substantial yield from the process requiring 10 min to thresh 1 kg of Finger Millet, showcasing a relatively efficient and time-effective operation. Furthermore, the machine could thresh 6–7 kg of Finger Millet per hour, demonstrating a reasonably high throughput for larger quantities and the threshing machine had an efficiency rate of 60–70%, indicating its effectiveness in separating the Finger Millet from the ear buds. The machine's size, weight, and ease of transportation would be useful data for a complete evaluation of its portability.

The fabricated model appeared to offer a good balance between efficiency, capacity, and yield, while also taking into consideration cost and portability. Nonetheless, detailed cost and portability information would enhance the overall understanding of the machine's suitability for various end users.

Conclusion

The product was built and tested keeping small land holders in mind, especially those in regional areas, particularly in the north and south of Karnataka, India. The final fabricated model for threshing Finger Millet optimized efficiency, cost, and portability. End-user validation showed that threshing 1 kg of dry ear buds yielded 0.5 kg of Finger Millet in 10 min, with a machine capacity of 6–7 kg/hr and an efficiency rate of 60–70%. The machine's size, weight, and transportability contributed to its overall suitability. However, detailed cost and portability assessments are needed for a comprehensive evaluation. Overall, the fabricated model balanced efficiency, capacity, yield and portability, making it potentially beneficial for diverse end users.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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