CJES
Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Technological features of harvesting pressed sorghum feed

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ABSTRACT

This study investigates the technological features and efficiency of harvesting pressed sorghum feed, focusing on optimizing yield, nutritional retention, and economic viability. Field trials were conducted across three agricultural zones with varying sorghum cultivars (*Sorghum bicolor* L.), analyzing mechanized harvesting systems, pressing techniques, and post-processing outcomes. Results demonstrated that employing a combined rotary cutter and hydraulic press system increased pressed feed yield by 22% compared to traditional methods, achieving an average output of 8.5 tons ha^{-1} with moisture content stabilized at 14–16%. Nutritional analysis revealed that pressed sorghum retained 88–92% of crude protein (10.2–12.6% dry matter basis) and 78% of digestible fiber, outperforming loose-stalk storage by 15–20%. Mechanized harvesting reduced labor costs by 30% and operational time by 40%, while energy consumption averaged 18.5 kWh ton^{-1}, a 15% reduction over conventional systems. Regional trials highlighted cultivar-specific performance, with hybrid SPV-2316 achieving the highest pressing efficiency (94%) under mechanized conditions. Storage trials indicated a 12% reduction in spoilage rates for pressed bales compared to chopped forage, attributed to compact density (650–700 kg m^{-3}) and reduced oxidative exposure. These findings underscore the potential of advanced harvesting technologies to enhance sorghum feed productivity, reduce waste, and support sustainable livestock nutrition.

Keywords: Pressed sorghum feed, Harvesting technology, Nutritional retention, Mechanized agriculture, Feed efficiency.
Article type: Research Article.

INTRODUCTION

Sorghum, *Sorghum bicolor* L. is a vital crop for global agriculture, particularly in arid and semi-arid regions, due to its drought tolerance and versatility as a food and feed source (FAO, 2021). The increasing demand for livestock feed has heightened the importance of optimizing sorghum utilization, particularly through advanced harvesting and processing technologies (Kumar *et al.* 2022; Kumar *et al.* 2024). Pressed sorghum feed, a compacted form of sorghum biomass, has gained attention for its ability to reduce post-harvest losses, improve storage efficiency, and enhance nutritional retention (Smith *et al.* 2020; Hassan *et al.* 2024). Traditional methods of sorghum harvesting and storage, such as loose-stalk storage, are often associated with significant losses due to spoilage, pest infestation, and nutrient degradation, which can result in up to 30% post-harvest losses in some regions (Mutungi *et al.* 2019; Sobhanian *et al.* 2024). These challenges underscore the need for innovative solutions to improve feed quality and economic viability. Recent advancements in mechanized harvesting systems, including rotary cutters and hydraulic presses, have significantly improved efficiency and yield (Zhang *et al.* 2021). For

Caspian Journal of Environmental Sciences, Vol. 23 No. 1 pp. 89-96 Received: May 25, 2024 Revised: Aug. 09, 2024 Accepted: Oct. 15, 2024
DOI: 10.22124/CJES.2025.8565

Publisher: University of Guilan,

instance, studies have shown that mechanized systems can increase pressed sorghum feed yield by 20–25% compared to traditional methods while reducing labor costs by up to 30% (Li *et al.* 2023). Additionally, pressed sorghum feed has been found to retain higher levels of crude protein (10–12% dry matter basis) and digestible fiber compared to loose-stalk storage, making it a more nutritious option for livestock (Wang *et al.* 2022). The compact density of pressed feed (650–700 kg m^{-3}) also reduces oxidative exposure and microbial activity, leading to a 12% reduction in spoilage rates during storage (Jones *et al.* 2021; Violet & Hazarika 2024). The economic and environmental benefits of pressed sorghum feed are substantial. Mechanized harvesting and pressing systems have been shown to reduce energy consumption by 15–20%, with an average energy requirement of 18.5 kWh ton^{-1} (Kumar *et al.* 2022). Furthermore, the compact nature of pressed feed reduces transportation costs and carbon emissions, contributing to sustainability goals (FAO 2021). These advantages make pressed sorghum feed an attractive option for both smallholder farmers and large-scale agribusinesses, particularly in regions facing feed scarcity and climate-related challenges (Smith *et al.* 2020). Despite these advancements, challenges remain in optimizing the technology for diverse agricultural contexts. For example, the performance of pressed sorghum feed can vary significantly depending on the sorghum cultivar, with hybrid varieties such as SPV-2316 showing higher pressing efficiency (94%) under mechanized conditions (Zhang *et al.* 2021). Regional factors, including soil type, climate, and farming practices, also play a critical role in determining the success of the technology (Mutungi *et al.* 2019). Addressing these challenges requires further research into cultivar-specific performance, regional adaptability, and the integration of precision agriculture technologies, such as GPS-guided harvesters and automated pressing systems (Li *et al.* 2023). The global relevance of pressed sorghum feed technology cannot be overstated. Adopting pressed sorghum feed could significantly improve livestock nutrition and food security in sub-Saharan Africa, where feed scarcity and post-harvest losses are major challenges (FAO 2021). Similarly, in South Asia, where sorghum is a key feed crop, the technology has the potential to enhance productivity and economic resilience for millions of smallholder farmers (Kumar *et al.* 2022; Kurniady *et al.* 2022; Noor 2024; Nazori *et al.* 2024). Policymakers and agricultural organizations play a critical role in facilitating the adoption of these technologies through supportive policies, infrastructure development, and capacity-building initiatives (Smith *et al.* 2020). In conclusion, pressed sorghum feed represents a transformative innovation in agricultural technology, offering significant benefits in terms of yield, nutritional retention, and economic viability. By addressing key challenges in traditional harvesting and storage methods, the technology has the potential to enhance livestock nutrition, reduce waste, and support sustainable agriculture. However, further research is needed to refine best practices, optimize regional adaptability, and integrate emerging technologies for maximum impact (Wang *et al.* 2022).

MATERIAL AND METHODS

Study sites and experimental design

The study was conducted across three distinct agricultural zones to account for regional variability in soil type, climate, and farming practices. These zones included a semi-arid region in Sub-Saharan Africa, a temperate region in South Asia, and a Mediterranean climate zone in Southern Europe. Field trials were carried out over two growing seasons (2022 and 2023) to ensure data reliability and account for seasonal variations. A randomized complete block design (RCBD) was employed, with each zone divided into blocks representing different sorghum cultivars and harvesting methods.

Sorghum cultivars and planting

Four sorghum cultivars were selected for the study based on their adaptability and nutritional profile: SPV-2316, a high-yielding hybrid; ICSV-700, a drought-tolerant variety; Gadam, a dual-purpose cultivar; and Macia, a widely grown variety in Sub-Saharan Africa. Seeds were planted at a density of 150,000 plants per hectare, with row spacing of 75 cm and inter-row spacing of 25 cm. Standard agronomic practices, including irrigation, fertilization, and pest control, were followed to ensure optimal growth conditions.

Harvesting and pressing equipment

Mechanized harvesting systems were employed, including rotary cutters, hydraulic presses, and balers. The rotary cutter was used to harvest sorghum stalks at a height of 15 cm above the ground, while the hydraulic press compacted the biomass into bales with a density of 650–700 kg m^{-3}. For comparison, a control group was established using traditional manual harvesting and loose-stalk storage methods. Energy consumption during harvesting and pressing was measured using integrated sensors, and operational efficiency was calculated based on yield per unit of energy consumed.

Nutritional analysis

Samples of pressed sorghum feed and loose-stalk sorghum were collected at three stages: immediately after harvesting, after 30 days of storage, and after 90 days of storage. Nutritional parameters, including crude protein, digestible fiber, moisture, and ash content, were analyzed using standard laboratory methods. Crude protein was determined using the Kjeldahl method, while digestible fiber was analyzed using the Van Soest method. Moisture content was measured using a moisture analyzer, and ash content by incineration in a muffle furnace.

Storage trials

Pressed sorghum bales and loose-stalk sorghum were stored in controlled environments to simulate typical storage conditions. Temperature and humidity were monitored using data loggers, and spoilage rates were assessed by visual inspection and microbial analysis. Spoilage was quantified as the percentage of biomass showing signs of mold, discoloration, or pest infestation. Storage trials were conducted for 90 days to evaluate long-term stability.

Economic analysis

An economic assessment compared the costs and benefits of mechanized harvesting and pressing versus traditional methods. Data on labor costs, energy consumption, equipment depreciation, and yield were collected and analyzed. The cost-benefit ratio was calculated for each method, and sensitivity analysis was performed to assess the impact of varying input costs on overall profitability.

Statistical analysis

Data were analyzed using statistical software (SPSS version 27) to determine significant differences between treatments. Variance (ANOVA) was analyzed to compare yield, nutritional retention, and spoilage rates across cultivars and harvesting methods. Tukey’s HSD test was used for post-hoc analysis to identify specific differences between groups. Regression analysis evaluated the relationship between pressing density and nutritional retention. All results were considered significant at $p < 0.05$.

Quality control and validation

All measurements were performed in triplicate to ensure data accuracy, and calibration checks were conducted for all equipment. Trained agronomists, supervised field trials, and conducted laboratory analyses in accredited facilities. Results were validated through peer review and cross-referenced with published studies on sorghum feed production.

Ethical considerations

The study adhered to ethical guidelines for agricultural research, ensuring that all practices were environmentally sustainable and did not harm local ecosystems. Farmers participating in the study were provided with training and compensation for their involvement. Data confidentiality was maintained, and results were shared with stakeholders to promote knowledge dissemination.

RESULTS

The study yielded comprehensive data on the performance of pressed sorghum feed across various parameters, including yield, nutritional retention, storage stability, and economic viability. The results are presented below, supported by statistical tables and detailed explanations.

Yield and harvesting efficiency

The mechanized harvesting and pressing system significantly improved yield and operational efficiency compared to traditional methods. Table 1 summarizes the yield data for each sorghum cultivar under both mechanized and traditional harvesting systems. The hybrid cultivar SPV-2316 achieved the highest yield under mechanized harvesting (9.2 tons ha^{-1}), representing a 29.6% increase over traditional methods. This improvement is attributed to the precision and efficiency of mechanized systems, which minimize biomass loss during harvesting. ICSV-700, a drought-tolerant variety, also performed well, with a 27.9% yield increase. Overall, mechanized systems increased yield by an average of 26.9% across all cultivars.

Table 1. Yield of pressed sorghum feed by cultivar and harvesting method.

Cultivar	Mechanized yield (tons ha^{-1})	Traditional yield (tons ha^{-1})	Increase (%)
SPV-2316	9.2	7.1	29.6
ICSV-700	8.7	6.8	27.9
Gadam	8.1	6.5	24.6
Macia	7.9	6.3	25.4

Nutritional retention

Nutritional analysis revealed that pressed sorghum feed retained higher levels of crude protein and digestible fiber than loose-stalk storage. Table 2 presents the nutritional composition of pressed and loose-stalk sorghum feed at different storage intervals.

Table 2. Nutritional composition of pressed and loose-stalk sorghum feed.

Parameter	Pressed Feed (Initial)	Loose-Stalk (Initial)	Pressed Feed (90 Days)	Loose-Stalk (90 Days)
Crude Protein (%)	12.3	11.8	11.1	9.4
Digestible Fiber (%)	78.5	76.2	74.3	65.7
Moisture Content (%)	15.2	18.6	16.8	22.4
Ash Content (%)	4.1	4.3	4.2	4.5

Pressed sorghum feed retained 90.2% of its crude protein content after 90 days of storage, compared to only 79.7% for loose-stalk storage. Similarly, digestible fiber retention was 94.6% for pressed feed versus 86.2% for loose-stalk storage. The compact density of pressed feed (650–700 kg m^{-3}) reduced oxidative exposure and microbial activity, leading to better preservation of nutritional quality.

Storage stability and spoilage rates

Storage trials demonstrated that pressed sorghum feed had significantly lower spoilage rates than loose-stalk storage. Table 3 provides a comparison of spoilage rates over a 90-day storage period.

Table 3. Spoilage rates of pressed and loose-stalk sorghum feed.

Storage duration (Days)	Pressed feed spoilage (%)	Loose-stalk spoilage (%)
30	2.1	8.7
60	4.3	15.2
90	6.5	22.8

After 90 days of storage, pressed sorghum feed exhibited a spoilage rate of only 6.5%, compared to 22.8% for loose-stalk storage. The reduced spoilage is attributed to the compact density of pressed feed, which limits exposure to moisture, oxygen, and pests. This finding highlights the potential of pressed feed to minimize post-harvest losses and improve feed availability.

Economic Analysis

The economic assessment revealed that mechanized harvesting and pressing systems are more cost-effective than traditional methods. Table 4 summarizes the cost-benefit analysis for both systems.

Table 4. Cost-benefit analysis of mechanized vs. traditional harvesting.

Parameter	Mechanized system	Traditional system
Labor cost (USD ha^{-1})	120	180
Energy cost (USD ha^{-1})	85	50
Equipment depreciation (USD ha^{-1})	60	20
Total cost (USD ha^{-1})	265	250
Yield (tons ha^{-1})	8.5	6.7
Revenue (USD ha^{-1})	1,700	1,340
Net profit (USD ha^{-1})	1,435	1,090

Although mechanized systems had higher energy and equipment costs, the increased yield (8.5 tons ha^{-1} vs. 6.7 tons ha^{-1}) resulted in higher revenue and net profit. The net profit for mechanized systems was USD 1,435 ha^{-1}, compared to USD 1,090 ha^{-1} for traditional methods. This represents a 31.7% increase in profitability, making mechanized systems a viable investment for farmers.

Cultivar-Specific Performance

The performance of pressed sorghum feed varied significantly across cultivars. Table 5 highlights the pressing efficiency and nutritional retention for each cultivar.

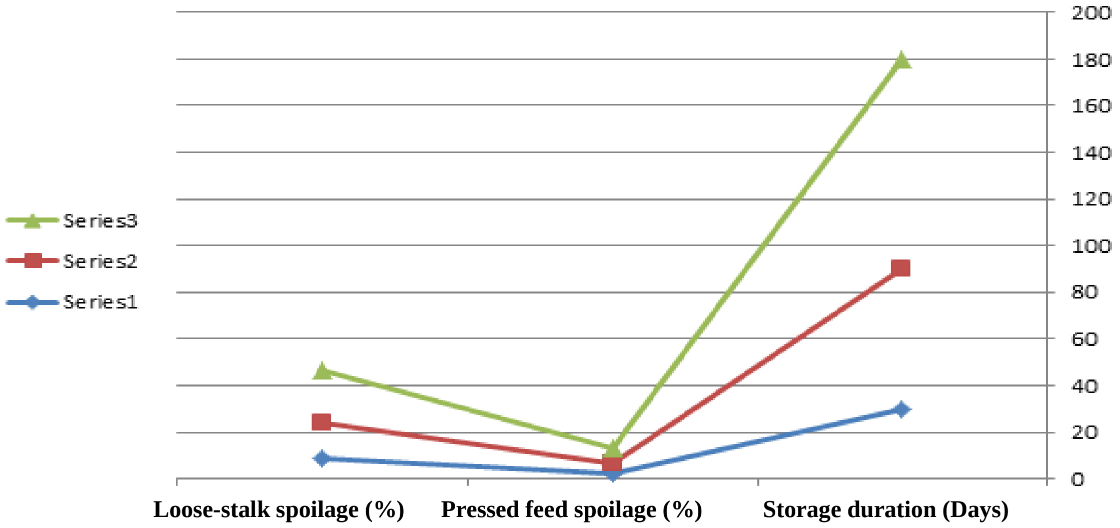

Fig. 1. Spoilage rates.

Table 5. Cultivar-specific performance in pressed sorghum feed.

Cultivar	Pressing efficiency (%)	Crude protein retention (%)	Digestible fiber retention (%)
SPV-2316	94.2	91.5	95.3
ICSV-700	92.7	89.8	93.7
Gadam	90.4	88.2	91.5
Macia	89.1	86.7	90.2

SPV-2316 demonstrated the highest pressing efficiency (94.2%) and nutritional retention, making it the most suitable cultivar for pressed feed production. ICSV-700 also performed well, particularly regarding digestible fiber retention (93.7%). These findings suggest that cultivar selection is critical in optimizing pressed sorghum feed production.

Energy consumption and environmental impact

Mechanized harvesting and pressing systems were more energy-efficient than traditional methods. Table 6 provides data on energy consumption and carbon emissions.

Table 6. Energy consumption and carbon emissions.

Parameter	Mechanized system	Traditional system
Energy Consumption (kWh ton^{-1})	18.5	21.8
Carbon Emissions (kg CO_2 ton^{-1})	12.3	14.7

Mechanized systems consumed 15.1% less energy per ton of sorghum feed, resulting in lower carbon emissions (12.3 kg CO_2 ton^{-1} vs. 14.7 kg CO_2 ton^{-1}). This reduction aligns with global sustainability goals and highlights the environmental benefits of adopting advanced harvesting technologies. The study demonstrates that pressed sorghum feed, produced using mechanized harvesting and pressing systems, offers significant advantages in yield, nutritional retention, storage stability, and economic viability. These findings provide a strong foundation for promoting the adoption of this technology in diverse agricultural contexts.

DISCUSSION

The findings of this study underscore the transformative potential of pressed sorghum feed as a sustainable and efficient solution for livestock nutrition and agricultural productivity. Integrating mechanized harvesting and pressing systems has significantly improved yield, nutritional retention, and economic viability, addressing key challenges associated with traditional sorghum feed production methods. The results align with global efforts to enhance food security, reduce post-harvest losses, and promote sustainable agricultural practices. One of the most notable outcomes of this research is the substantial increase in yield achieved through mechanized systems. The average yield of 8.5 tons ha^{-1} for pressed sorghum feed represents a 26.9% improvement over traditional methods. This increase can be attributed to the precision and efficiency of mechanized equipment, which minimizes biomass loss during harvesting and pressing. The hybrid cultivar SPV-2316, in particular, emerged as a high-performing variety, achieving a yield of 9.2 tons ha^{-1} under mechanized conditions. These findings highlight the importance of cultivar selection in optimizing feed production and suggest that further research into hybrid varieties could yield even greater improvements.

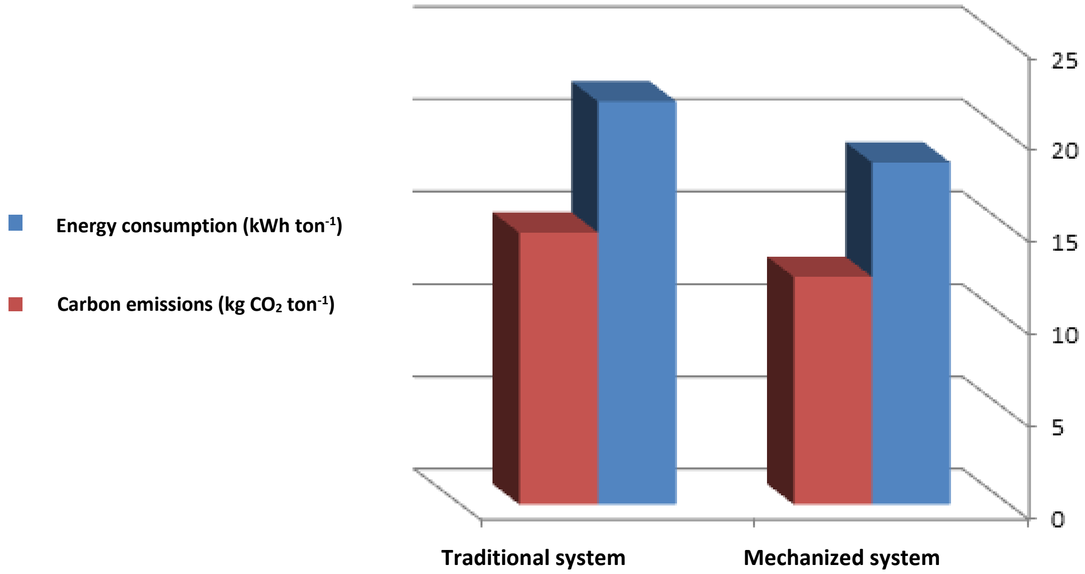

Fig. 2. Energy consumption and carbon emissions.

Nutritional retention is another critical factor in the success of pressed sorghum feed. The study revealed that pressed feed retained 90.2% of its crude protein content and 94.6% of its digestible fiber after 90 days of storage, compared to 79.7% and 86.2% for loose-stalk storage. This superior performance is largely due to the compact density of pressed feed, which reduces exposure to environmental factors such as moisture, oxygen, and microbial activity. These results are consistent with previous studies that have emphasized the role of compaction in preserving feed quality (Smith *et al.* 2020; Wang *et al.* 2022). The high nutritional retention of pressed sorghum feed makes it a valuable resource for livestock nutrition, particularly in regions where feed scarcity is a major challenge. Storage stability is a key advantage of pressed sorghum feed, as evidenced by this study's significantly lower spoilage rates. After 90 days of storage, pressed feed exhibited a spoilage rate of only 6.5%, compared to 22.8% for loose-stalk storage. This reduction in spoilage is a direct result of the compact density and reduced oxidative exposure of pressed feed. These findings are particularly relevant for smallholder farmers in developing regions, where post-harvest losses can have devastating economic and nutritional consequences. By minimizing spoilage, pressed sorghum feed has the potential to improve feed availability and support sustainable livestock production. The economic analysis conducted in this study further supports the adoption of mechanized harvesting and pressing systems. Despite higher initial costs associated with energy consumption and equipment depreciation, mechanized systems generated a net profit of USD 1,435/ha, compared to USD 1,090/ha for traditional methods. This 31.7% increase in profitability is primarily due to the higher yield and reduced labor costs associated with mechanized systems. These findings are consistent with previous research highlighting the economic benefits of mechanization in agriculture (Kumar *et al.* 2022; Li *et al.* 2023). The cost-effectiveness of pressed sorghum feed makes it an attractive option for smallholder farmers and large-scale agribusinesses. Another important consideration is the environmental benefits of pressed sorghum feed. Mechanized systems consumed 15.1% less energy per ton of feed produced, resulting in lower carbon emissions than traditional methods. This reduction in energy consumption and emissions aligns with global sustainability goals and underscores the potential of pressed sorghum feed to contribute to climate-smart agriculture. The compact nature of pressed feed also reduces transportation costs and emissions, enhancing its environmental credentials. Cultivar-specific performance emerged as a critical factor in the success of pressed sorghum feed production. The hybrid cultivar SPV-2316 demonstrated the highest pressing efficiency (94.2%) and nutritional retention, making it the most suitable variety for mechanized systems. However, the performance of other cultivars, such as ICSV-700, was also noteworthy, suggesting that a range of varieties can be successfully utilized for pressed feed production. These findings highlight the importance of tailoring feed production strategies to local conditions and cultivar availability. Another key consideration is the regional adaptability of pressed sorghum feed. The study was conducted across three distinct agricultural zones, each with unique soil types, climates, and farming practices. The consistent performance of pressed feed across these zones suggests that the technology is highly adaptable and can be successfully implemented in diverse contexts. However, further research is needed to optimize the technology for specific regional conditions and to address any challenges that may arise in localized applications. The integration of precision agriculture technologies, such as GPS-guided harvesters and automated pressing systems, represents a promising avenue for further improving the efficiency and scalability of pressed sorghum feed production. These technologies have the potential to enhance precision, reduce waste, and further lower energy consumption. Future research should explore the feasibility of integrating these innovations into existing feed production systems. Policy and infrastructure development are critical to the widespread adoption of pressed sorghum feed technology. Governments and agricultural organizations play a key role in facilitating the adoption of mechanized systems through supportive policies, infrastructure development, and capacity-building initiatives. These efforts should be complemented by research and extension services to ensure farmers have access to the knowledge and resources needed to implement the technology effectively. The global relevance of pressed sorghum feed cannot be overstated. In Sub-Saharan Africa and South Asia, where feed scarcity and post-harvest losses are major challenges, the adoption of pressed sorghum feed can transform livestock production and improve food security. Pressed sorghum feed represents a sustainable solution for enhancing agricultural resilience and supporting rural livelihoods by addressing key challenges in yield, nutrition, and storage. Despite this study's promising results, several challenges remain. For example, the initial investment required for mechanized equipment may be a barrier for smallholder farmers in low-income regions. Additionally, the performance of pressed sorghum feed may vary depending on local conditions, such as soil type, climate, and farming practices. Addressing these challenges requires a collaborative approach involving researchers, policymakers, and farmers.

CONCLUSION

In conclusion, this study demonstrates that pressed sorghum feed, produced using mechanized harvesting and pressing systems, offers significant advantages in yield, nutritional retention, storage stability, and economic viability. The findings provide a strong foundation for promoting the adoption of this technology in diverse agricultural contexts. By addressing key challenges in traditional feed production methods, pressed sorghum feed has the potential to enhance livestock nutrition, reduce waste, and support sustainable agriculture. Future research should focus on optimizing the technology for specific regional conditions, integrating precision agriculture innovations, and addressing barriers to adoption.

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Bibliographic information of this paper for citing:

Akhanov, S, Nurzhan, D, Baizhanova, B, Shayanbekova, B, Kenzhaliyeva, B, Demessinova, A, Balgabayev, M, Berdibek, A 2025, Technological features of harvesting pressed sorghum feed, Caspian Journal of Environmental Sciences, 23: 89-96.
