BORNEO JOURNAL OF SCIENCES AND TECHNOLOGY (BJoST)
VOL. : 7, ISSUE: 1, 76-85
DOI: http://doi.org/10.35370/bjost.2025.7.1-09
e-ISSN: 2672-7439 © 2018, UTS Publisher.

University of Technology Sarawak

ORIGINAL ARTICLE

The Potential Application of Sago Dregs and Kenaf Seed Waste as Main Ingredients for Animal Feed Production_A Narrative Review

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ABSTRACT - Animal feed is crucial in the agricultural industry, particularly in the livestock sector. Utilising agricultural waste to produce animal feed is a sustainable approach that has the potential to establish a more stable and environmentally-friendly farming. This narrative review paper emphasises the potential of sago dregs and kenaf seed waste, which are agricultural waste materials, as the primary components in animal feed production. This study also enumerates the benefits and difficulties that have been achieved and must be confronted in the process of adapting these two materials as the primary component in the manufacturing of animal feed products. After analysing the literature and interpreting the results, the group of writers is certain that these two materials may effectively support sustainable animal feed production. Future investigations are expected to explore the potential adaptation of these composite materials to animal diets.

ARTICLE HISTORY
Received: 15 July 2024
Revised: 25 Nov 2024
Accepted: 27 Dec 2024

KEYWORDS
Sago Dregs,
Kenaf Seed Waste,
Animal Feed,
Sustainable,

INTRODUCTION

The challenges animal feed producers face in the current landscape are multifaceted and encompass various aspects that impact the safety, quality, and sustainability of feed production. One significant challenge revolves around the increasing complexity of feed ingredients, as large-scale animal husbandry operations have led to modifications in animal feeds, incorporating ingredients such as rendered animals, animal waste, antibiotics, and organoarsenicals Sapkota et al. [1]. This shift towards diverse feed components raises concerns about food safety, animal health, and potential impacts on human health due to the inclusion of unconventional ingredients in animal feeds. Another critical challenge is the risk of pathogenic contamination in animal feed manufacturing facilities, which can have severe consequences on both animal and human health. Pathogenic microorganisms from colonized animals can contaminate slaughter by-product ingredients used in feed production, leading to potential infections in food animals and subsequent risks to the human food supply chain [2]. Ensuring effective pathogen decontamination protocols in feed mills is essential to mitigate these risks and safeguard animal and public health.

Food adulteration and feed contamination pose significant challenges in the food and feed industry, particularly concerning meat products [3]. The presence of contaminants in feeds can compromise animal health, food safety, and consumer trust. Addressing issues related to food and feed adulteration requires robust monitoring, testing, and regulatory measures to uphold quality standards and prevent fraudulent practices in the supply chain. Moreover, the threat of viral infections, such as porcine epidemic diarrhea

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virus (PEDV), in animal feed manufacturing facilities necessitates stringent biosecurity measures and sterilization protocols to prevent the spread of pathogens [4]. Developing strategies to exclude and reduce the pathogenic load of viruses in feed and ingredients is crucial to prevent disease outbreaks and ensure the safety of animal products.

Microbial contaminants associated with commercial poultry feeds present ongoing challenges in feed safety and quality assurance [5]. Instances of food safety crises, such as the outbreak of bovine encephalopathy (BSE) and the Belgian dioxin crisis, underscore the importance of stringent quality control measures in feed manufacturing to prevent contamination and ensure the integrity of animal feeds. Furthermore, during drought and feed scarcity, the need to produce readily available, nutritionally balanced feeds at low cost becomes a pressing challenge for animal feed producers [6]. Developing innovative feed formulations that meet the nutritional requirements of animals while optimizing resource utilization and cost-effectiveness is essential to address feed shortages and maintain animal health and productivity. The challenges stated in the preceding statement should be treated with utmost seriousness, and a definitive solution must be implemented to prevent any disruption or negative impact on the country's food sector. Hence, the author contends that the use of sustainable resources is a favourable measure in addressing these concerns.

SUSTAINABLE MATERIAL TO SOLVE ANIMAL FEED PRODUCTION CHALLENGES

Producing animal feed from sustainable materials is crucial due to various interconnected reasons that encompass environmental, economic, and social dimensions. The increasing global demand for livestock products requires a transition to sustainable feed sources to reduce strain on natural resources and combat environmental degradation [7]. Feeds constitute a significant portion of the environmental footprint of livestock production, affecting land, energy, and water resources [7]. Shifting to alternative sustainable ingredients for animal diets, such as insect-based feeds or fermented plant biomass, can decrease the environmental impact of feed production, contributing to overall sustainability efforts [8 - 9]. Moreover, the sustainability of livestock production systems is closely linked to animal feed availability and quality [10]. To ensure the long-term sustainability of livestock production, it is vital to consider the sustainability of feed sources alongside animal product consumption [10]. Sustainable feeds sourced from materials like forage legumes or hydroponic fodder enhance animal nutrition and promote environmental security by improving resource utilization efficiency [11 - 12]. These alternative feed sources offer a way to boost the sustainability of animal agriculture by reducing dependence on traditional feed sources that may compete with human food crops [13 - 14].

In addition to environmental concerns, the economic viability of livestock production is intricately connected to the sustainability of animal feed sources [15]. Developing efficient feeds and feeding systems from sustainable materials is essential to meet the rising demand for livestock products while ensuring profitability and competitiveness in the global market [15]. By utilizing food waste and crop biomass for innovative feed production, agri-food systems can enhance efficiency and resource utilization, strengthening the economic sustainability of livestock production [16]. Furthermore, the social aspect of sustainable animal feed production emphasizes the importance of meeting consumer preferences for natural and sustainable products [17]. As consumers increasingly seek ethically produced and environmentally friendly animal-sourced foods, adopting organic feeds and sustainable feeding practices becomes crucial for the livestock sector to align with evolving market demands [17]. Sustainable feed strategies that address the relationship between water use in feed production and livestock systems can contribute to a more sustainable water future while meeting the needs of a growing population [18].

The role of sustainable feeds in improving animal health, productivity, and welfare further highlights the necessity of transitioning to environmentally friendly feed sources [19]. Effective feed management not only enhances productivity and production outcomes but also plays a key role in maintaining the sustainability of livestock operations [19]. By incorporating nutrient-rich alternatives like spirulina into animal diets, the potential to enhance productivity while addressing sustainability challenges is demonstrated [20]. The necessity to produce animal feed from sustainable materials arises from a multifaceted rationale covering environmental stewardship, economic viability, social responsibility, and animal welfare.

THE OVERVIEW OF SAGO DREGS AND KENAF SEED WASTE IN INDUSTRIAL APPLICATION

Sago dregs, a by-product of sago starch processing, consists of cellular residues of fibrous sago pith, sago bark, and wastewater [21]. Efforts in sago waste management are essential to enhance yield, efficiency, and reduce waste, emphasizing the need for improved processing layouts, suitable drying methods, and the adoption of technologies to generate additional income for farmers and small-scale sago refineries [22]. This waste, rich in lignocellulosic materials like cellulose, hemicellulose, and lignin, presents opportunities for diverse applications beyond its conventional disposal methods [23]. The potential of sago dregs extends to bioethanol production, where sago solid waste serves as a valuable raw material for bioethanol manufacturing, highlighting its versatility and contribution to sustainable practices [24]. Furthermore, studies have explored the utilization of sago dregs in solid substrate fermentation to evaluate its viability as a feed ingredient, showcasing the multifaceted nature of this agricultural residue [23]. Additionally, sago dregs have been investigated for their adsorption capabilities, including removing heavy metals like lead and copper, further underlining their environmental remediation potential [25].

Moreover, sago dregs have been considered for applications in construction materials, with research focusing on incorporating sago fine waste into cement bricks to enhance their properties, demonstrating the feasibility of utilizing sago waste in innovative ways [26]. The exploration of sago dregs in forming porous clay ceramics emphasizes the resourcefulness of incorporating waste materials into value-added products, showcasing the sustainable utilization of sago waste in diverse industries [27]. Additionally, sago fine waste has been studied as a potential sand replacement material in cement bricks, indicating its adaptability in construction applications [28]. Furthermore, sago dregs has been investigated for its potential in biogas production, emphasizing its lignocellulosic composition and suitability for generating renewable energy sources, aligning with the global shift towards sustainable energy practices [29]. The utilization of sago dregs for biobutanol production through saccharification and fermentation processes underscores the resourcefulness of sago waste in biofuel production, contributing to the renewable energy sector [30]. Additionally, the preparation of cellulose hydrogel from sago pith waste for seed germination purposes highlights the innovative applications of sago waste in agricultural practices, showcasing its potential in enhancing crop cultivation methods [31].

Moreover, sago waste has been explored for its potential in producing biochar, with studies indicating the nutritional characteristics of biochar derived from sago waste, underscoring its value in soil amendment and agricultural practices [32]. The synthesis of biofoam from sago waste for biodegradable food storage applications showcases the versatility of sago waste in developing eco-friendly materials, aligning with sustainable packaging solutions [33]. The development of a sustainable sago-based value chain through optimization approaches emphasizes the holistic utilization of sago waste in creating a circular economy model, promoting resource efficiency and waste reduction [34].

Kenaf seed waste, a by-product of kenaf seed oil extraction, is a valuable agricultural residue that offers various opportunities for utilization across different industries. Kenaf seeds, which contain approximately 20% oil, are a potential source of edible oil comparable to other common oilseeds like cottonseed and soybean [35]. The extraction process of kenaf seed oil results in the generation of defatted kenaf seed meal (DKSM), which accounts for over 75% of the seed mass and is considered a secondary waste product [36]. Typically, kenaf seeds are discarded as waste material after oil extraction, highlighting the need to explore sustainable ways to utilize this underutilized resource [37]. Studies have shown that kenaf seed waste possesses high protein (22–31%) and oil (22–25%) contents, indicating its potential for various food applications [38]. Additionally, kenaf seed waste has been investigated for its antioxidant properties, with research focusing on the bioactivities of kenaf biomass extracts retrieved from different parts of the plant, including the seeds [39]. The bioactivities and phytochemical composition of kenaf seeds make them a promising candidate for health applications, emphasizing the importance of exploring the nutritional and polyphenolic compounds present in underutilized plant seeds [40].

Furthermore, kenaf seed waste has been studied for its potential in producing edible flour with high antioxidant activity, showcasing the value that can be derived from this agricultural by-product [37]. The amino acid profile of kenaf seeds indicates richness in specific amino acids like L-4hydroxyproline, glutamate, and arginine, highlighting the nutritional composition of kenaf seed waste [41]. Moreover, kenaf seed waste has been explored for its potential in protecting against oxidative stress and inflammation, demonstrating its role in promoting health and well-being [36]. The utilization of kenaf seed waste in the production of value-added plant-based foods has been highlighted as a potential avenue for enhancing the nutritional profile of food products [42]. Additionally, kenaf seed waste has been studied for its phenolic antioxidant content, with research focusing on the extraction methods and effects of different solvents on the antioxidant activities of kenaf seed extracts [43]. The presence of cardiac glycosides in kenaf seed oil further underscores the diverse bioactive compounds that can be derived from kenaf seed waste [35].

SAGO DREGS AND KENAF SEED WASTE AS POTENTIAL INGREDIENTS FOR ANIMAL FEED PRODUCTION

The nutritional potential of sago and kenaf seed waste for animal feed production can be explored through a detailed analysis of their composition. Sago, derived from the pith of tropical palm stems, and kenaf, a fiber-rich plant, offer promise as feed ingredients due to their unique nutritional profiles. Sago dregs, are rich in fiber and starch, making them suitable for ruminant feed [44]. Moreover, sago lignocellulose waste can be further optimized for animal feed by utilizing cellulase-, xylanase-, and mannanase-producing microbes [45]. On the other hand, kenaf seed waste, often discarded, contains essential nutrients and phytocompounds, making it appropriate for value-added plant-based foods [42]. Kenaf seed oil, characterized by its high oil content, can also be a potential source of edible oil [46].

In animal feed production, the nutritional value of these waste products is paramount. Fermented sago waste has been assessed for its potential as a feed ingredient for red hybrid tilapia, demonstrating its suitability as a feed component [47]. Similarly, studies have investigated the impact of fermented sago waste on goat consumption and digestion, underscoring the potential of incorporating sago waste into animal feed formulations [48]. Furthermore, the nutritional value of sago dregs is influenced by the fermentation process, highlighting the significance of processing techniques in enhancing its nutritional quality for cattle feed [49].

Regarding kenaf seed waste, its defatted meal has been identified as a potential edible flour with high antioxidant activity, suggesting its value as a nutritional component in animal feed [50]. Additionally, kenaf seed oil, rich in polyunsaturated fatty acids (PUFA) and phytosterols, offers health benefits and can be safeguarded through microencapsulation for feed applications [51]. The inclusion of kenaf seed oil in animal feed formulations could provide essential nutrients and bioactive compounds beneficial for animal health and growth.

When considering alternative feed ingredients, utilizing agricultural waste for animal feed production emerges as a sustainable approach. Research has explored the environmental implications of repurposing agricultural waste into animal feed, such as rice straw and citrus pruning waste, showcasing the potential for enhancing feed composition while reducing environmental impact [52]. Additionally, the assessment of agro-industrial byproducts, including sago residues, coconut meal, soybean-ketchup byproduct, among others, highlights the diverse array of potential feed materials available for ruminant animals.

The nutritional content of sago and kenaf seed waste presents promising opportunities for animal feed production. These waste products can be converted into valuable feed ingredients rich in essential nutrients, fibers, and bioactive compounds through appropriate processing techniques like fermentation and microbial treatment. The utilization of sago dregs, kenaf seed oil, and defatted kenaf seed meal in animal feed formulations demonstrates the potential for sustainable feed production while maximizing the nutritional value for livestock. By tapping into these underutilized resources and exploring innovative processing methods, the agricultural industry can enhance the nutritional quality of animal feeds, thereby promoting animal health and productivity.

ANIMAL FEED PROCESSING METHOD

Various processing methods can be employed to enhance the nutritional value, digestibility, and palatability of animal feed produced from sago and kenaf seed waste. One effective technique is solid substrate fermentation, which involves fermenting the waste materials under controlled conditions to improve their protein content and overall nutritional quality. Fermentation can help break down complex compounds, reduce anti-nutritional factors, and enhance the availability of nutrients, making the feed more suitable for animal consumption [53].

Another valuable method is ensiling, which entails fermenting and storing the waste materials under anaerobic conditions to improve their preservation and nutritional quality, making them more digestible and palatable for animals . Ensiling can also help reduce moisture content, enhance feed palatability, and extend the shelf-life of the feed formulations[54]. Mechanical processing techniques such as grinding, milling, and sieving can be utilized to reduce the particle size of sago and kenaf seed waste[55]. By breaking down the fibrous structures of the waste materials, mechanical processing can improve nutrient accessibility and enhance digestibility, making the feed more suitable for animal consumption[56].

Extrusion technology offers a promising approach to processing sago and kenaf seed waste into extruded feed pellets[57]. By applying heat, pressure, and mechanical shear, extrusion can transform the raw materials into uniform and compact feed pellets, improving nutrient retention, reducing anti-nutritional factors, and enhancing the overall quality of the feed [58] . The combination of solid substrate fermentation, ensiling, mechanical processing, and extrusion technology can effectively produce high-quality animal feed from sago and kenaf seed waste. These processing methods can enhance the nutritional value, digestibility, and overall quality of the feed formulations, contributing to improved animal health, performance, and sustainability in livestock production systems.

CHALLENGES AND LIMITATIONS

Anti-Nutritional Factors

The content of antinutritional factors in sago and kenaf seed waste can vary, including compounds such as tannins, phytates, lectins, trypsin inhibitors, and other substances that interfere with nutrient absorption and utilization in animals. These antinutritional factors, if not properly managed, can negatively impact animal health, growth, and performance. To address these challenges, several strategies can be employed to reduce or eliminate antinutritional factors and enhance the nutritional value of feed ingredients. Fermentation is one such strategy, as it can reduce antinutritional compounds, improve protein digestibility, and increase amino acid availability. Studies, such as those by Gilani et al. [59], highlight the role of fermentation in breaking down these compounds, making sago and kenaf seed waste more suitable for animal feed. Additionally, heat processing methods, including boiling, cooking, and roasting, are effective in inactivating antinutritional factors. For example, Mattos et al. [60] discuss how heat treatments can reduce tannins, which otherwise bind proteins and decrease digestibility.

Enzyme supplementation is another approach to improve nutrient utilization and mitigate the effects of antinutritional factors. References like Verni et al. [61] emphasize the role of exogenous enzymes in enhancing nutrient availability, making this method particularly useful for feed formulations containing sago and kenaf seed waste. Moreover, processing techniques such as soaking, ensiling, and drying can significantly reduce antinutritional factors and improve feed quality. Wildermuth et al. [62] underscore the importance of these methods in optimizing the nutritional value of feed ingredients. By employing fermentation, heat processing, enzyme supplementation, and other processing techniques, the antinutritional factors in sago and kenaf seed waste can be effectively managed. This ensures the production of high-quality animal feed that supports optimal animal health, growth, and performance.

Economic Feasibility

The processing of sago and kenaf seed waste into animal feed can face significant economic challenges. High processing costs, including expenses related to equipment, labor, and energy consumption, may outweigh the economic benefits of utilizing these waste materials, as noted by Sheldon [63]. Additionally, market demand and pricing play a crucial role in determining economic feasibility. Fluctuations in the prices of feed ingredients and shifting consumer preferences can directly impact the profitability of producing animal feed from waste materials [64]. In cases where economic incentives are limited, such as insufficient cost savings or low revenue generation, the feasibility of utilizing sago and kenaf seed waste becomes further constrained [65]. Regulatory compliance also adds another layer of cost, as meeting safety, quality, and environmental standards can increase production expenses and affect overall profitability [66].

Moreover, the need for substantial capital investment and infrastructure for processing waste materials poses a significant economic barrier. Establishing facilities, investing in technology, and managing ongoing operational costs may challenge the viability of feed production [67]. Waste management costs, including proper handling, storage, and disposal of waste, can further increase overall production expenses, reducing economic returns [68]. Lastly, competing priorities within the agricultural sector, such as limited financial resources and budget constraints, may hinder the allocation of funds toward implementing waste utilization strategies. These economic limitations can impede the adoption of cost-effective processes for converting sago and kenaf seed waste into animal feed [69].

MARKETING PROCEDURES FOR DEVELOPED PRODUCT INTO MARKET

In order to put animal feed derived from sago and kenaf seed waste into the agricultural market, it is advisable to follow a number of promising measures outlined in the existing literature. First and foremost, it is crucial to prioritise the sustainable management and utilisation of agri-food industry wastes and by-products as animal feed. This will ensure the creation of nutritional, cost-effective, and environmentally-friendly feed alternatives [70]. This strategy is in line with the idea of a circular food system, which involves repurposing waste materials to produce goods that have added value. This helps to minimise negative environmental effects and also meets the growing need for livestock feed [71]. In addition, investigating the use of tannery solid wastes as a viable animal feed offers a chance to introduce recycled products into the worldwide market. This highlights the significance of utilising non-traditional feed sources to improve sustainability in livestock production [72]. By harnessing untapped resources such as sago and kenaf seed waste, the agricultural industry may expand its range of feed options, hence increasing efficient use of resources and minimising waste production [73].

Incorporating kenaf seeds and their by-products into animal feed formulations can improve the quality of the feed and enhance animal health and performance, thanks to the nutritional benefits they provide. Kenaf seeds possess significant amounts of protein and oil, making them a great resource for creating nutritional feed alternatives. This aligns with the increasing need for sustainable and high-quality animal feeding. Moreover, utilising technical advancements to extract nutrients from waste and by-products of the food system can provide secondary materials that are acceptable for animal feed, so promoting a more sustainable and efficient method of producing feed [73]. By incorporating these reclaimed components into animal feed formulations, the agricultural industry can decrease its dependence on traditional feed sources and encourage the adoption of a more circular economy model [74].

CONCLUSION

In conclusion, animal feed made from sago dregs and kenaf seed waste could enhance sustainable agriculture and waste management. Farmers can follow circular economy concepts, reduce environmental impact, and increase animal production efficiency and sustainability by using agricultural leftovers as feed. Sago dregs and kenaf seed waste in animal feed formulations need more investigation on their economic feasibility and nutritional value. Finally, using sago and kenaf seed waste in animal feed production enhances nutrition, sustainability, phosphorus management, mineral bioavailability, environmental impact, economic opportunities, and value-added goods

ACKNOWLEDGEMENT

The authors would like to thank UTS for funding this work under an internal grant (2/2023/10).

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