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# Cashew Apple: Nutritional Composition, Nutritive Value and Potential as Commercial Feedstuff for Livestock

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ABSTRACT

Cashew (*Anacardium occidentale* L.) apple is an underutilized false fruit that accompanies the cashew nut. This review critically examines the nutrient composition, nutritive value, and potential of cashew apple as commercial feedstuff for livestock. It encompasses a comprehensive analysis of the various constituents present in cashew apple, including macronutrients, vitamins, minerals, and phytochemical factors. Cashew apple is composed of crude protein 10.52%, crude fibre 6.18%, ether extract 7.58, and metabolizable energy of 3489.42 Kcal/DM on an average basis. By synthesizing information from a wide range of studies, this review highlights the significant variations in the nutrient content of cashew apple and establishes various nutritive values for different livestock. Furthermore, this review suggests the need for further research to explore the full spectrum of health-promoting attributes and potential applications of cashew apple-derived components. Overall, this comprehensive assessment of the nutrient composition of cashew apple provides valuable insights for researchers, nutritionists, and food industry professionals seeking to unlock the nutritional potential of this often -overlooked fruit.

## Introduction

Feed accounts for about 65 – 75% cost of production (Gjesovska *et al*., 2014; Ojediran *et al.,* 2017; Moss *et al*., 2021; Okonkwo *et al*., 2022), thus, being a major challenge in livestock production. The development of low-cost feed ingredients (Oosting *et al*., 2021), unorthodox, and drought-resistant alternatives (Idahor, 2013; Alshelmani *et al*., 2021) like cashew (*Anacardium occidentale*) (Costa *et al*., 2021) for livestock is one of the solutions to the significant problems facing livestock production (rising production costs (Benoit and Mottet, 2023) and the need for sustainable production practices (Kaufmann, 2015).

Cashew apple, the fleshy fruit of the cashew tree, have traditionally been considered waste (Dheeraj *et al*., 2023; N'guessan *et al*., 2023) and discarded (Talasila and Shaik, 2013), but recent studies have demonstrated their high nutritional value and potential as a feedstuff for livestock (Dakuyo *et al*., 2022; Akyereko *et al*., 2023). Many studies have shown that cashew apple have a high nutritional value (Bhakyaraj and Singaravad, 2012; Das and Arora, 2017), containing crude protein, crude fat, crude fibre, and minerals and vitamins such as calcium, magnesium, potassium, and vitamin C (Ukonze *et al*., 2018; Oliveira *et al*., 2020; Akyereko *et al*., 2023). In addition, cashew apple have low lignin composition (de França Serpa *et al*., 2020), making them highly digestible and palatable to livestock (Araújo *et al*., 2022) and can replace feedstuff such as maize, soybean meal and others (Yisa *et al*., 2018).

Despite their potential as a feedstuff for livestock, the use of cashew apple faces several challenges (Akyereko *et al*., 2022), which include seasonality, short shelf life, and high moisture content, which can

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lead to spoilage and fermentation (Ahaotu and Ihekoronye, 2019; Araújo *et al*., 2019). Nevertheless, the development of new processing techniques, such as dehydration and ensiling has shown promising results in preserving the nutritional quality of cashew apple and increasing their shelf life (Costa *et al*., 2018; Liu *et al*., 2023).

The use of cashew apple as a feedstuff for livestock could provide a low-cost alternative to conventional feedstuffs thereby, promoting sustainable agricultural practices. By evaluating the nutritional content and nutritive value of cashew apple, the difficulties and challenges in using it as feed, and the possible advantages of using them as a feed resource for the livestock sector, this review investigated the cashew apple's potential as a feasible commercial feedstuff for animals. Additionally, this study aims to explore practical strategies and innovative processing methods to enhance the utilization of cashew apple as a sustainable and cost-effective feed resource, while addressing challenges related to preservation, processing, and economic integration into livestock systems.

## Cashew Apple Overview

### Production Over the years: Nuts and Cashew Apple

There has been a notable increase in global cashew production (Danso-Abbeam *et al*., 2021) with several countries contributing significantly to this trend. India, Nigeria (Oluwaseyi *et al*., 2022; Adeigbe *et al*., 2015), Cote d'Ivoire (Bassett, 2018), Vietnam, and numerous other countries are among the top producers of cashews (Mothe *et al*., 2017; FAOSTAT, 2023). The top ten cashew nut producers from 1994 to 2021 are shown in Figure 1. With an average output of 49.20% (1 259 566.51 tons), Africa leads the globe in cashew nut production by region. Asia comes in second with 44.40% (1 134 951.93 tons) and the Americas with 6.40% (164 158.75 tons) (FAOSTAT, 2023). From 1994 to 2021, India accounted for 592 573.93 tons of cashew nuts, followed by Nigeria (345 723.33 tons), Cote d'Ivoire (340 412.24 tons), Vietnam (212 081.55 tons), the Philippines (152 320.54 tons), Brazil (146 500.14 tons), Tanzania (130 492.39 tons), Indonesia (120 032.11 tons), the Republic of Benin (91 479.63), and Guniea-Bissau (91 283.18 tons), as shown in Figure 1. A sizeable portion of the global cashew output came from India and Vietnam, two of the leading growers and processors of cashew nuts (Bojang and Gibba, 2021). Both Nigeria and Cote d'Ivoire have contributed significantly to Africa's cashew nut output.

There are differences between the production trend of cashew apple when compared with the production of the nut. The majority of the cashew apple produced between 1994 and 2021 were produced by the Americas (89.10% - 1 561 988.02 tons) and Africa (10.10% - 190 947.29 tons) (FAOSTAT, 2023). Figure 2 shows the top cashew apple producers between 1994 and 2021. The top producer of cashew apple was Brazil (1 561 983.78 tons), followed by Mali (119 495.44 tons), Madagascar (71 451.84 tons) and Guyana (4.24 tons).

These contrasting trends underscore the need to focus on cashew apple by highlighting its untapped potential in regions like Africa. While Africa excels in cashew nut production, its relatively low cashew apple output suggests an underutilization of this by-product. Cashew apple are often discarded during nut processing (Dao *et al*., 2021a) despite its potential value as feedstuff in livestock.

Exploring how regions like Africa can leverage their cashew apple production more effectively could involve integrating cashew apple processing into the value chain, learning from Brazil's success in utilizing cashew apples, and tapping into new economic opportunities that this underutilized resource presents.

## Cashew Apple Wastage

Cashew nut is enclosed in a hard shell that contains a toxic oil known as cashew shell oil or CNSL (Cashew Nut Shell Liquid) (Taiwo, 2015; Mubofu and Mgaya, 2018). The cashew nuts must undergo a procedure known as "decortication" (Kabir and Fedele, 2018) which entails removing the cashew shell and extracting the CNSL, before they can be safely consumed. Large amounts of waste from the cashew apple decorticating process are produced and left on the field as agricultural waste (Prommajak *et al*., 2014). The pulp, skins, and other leftover fruit components from cashew apple make up the majority of this waste and are discarded or used as fertilizer (Dao *et al*., 2021a). Due to its high moisture content, cashew apple waste can present environmental problems (Andrade *et al*., 2015; van Walraven and Stark, 2024) if not handled appropriately. The amount of the left cashew apple is approximately ten times that of the collected nuts.

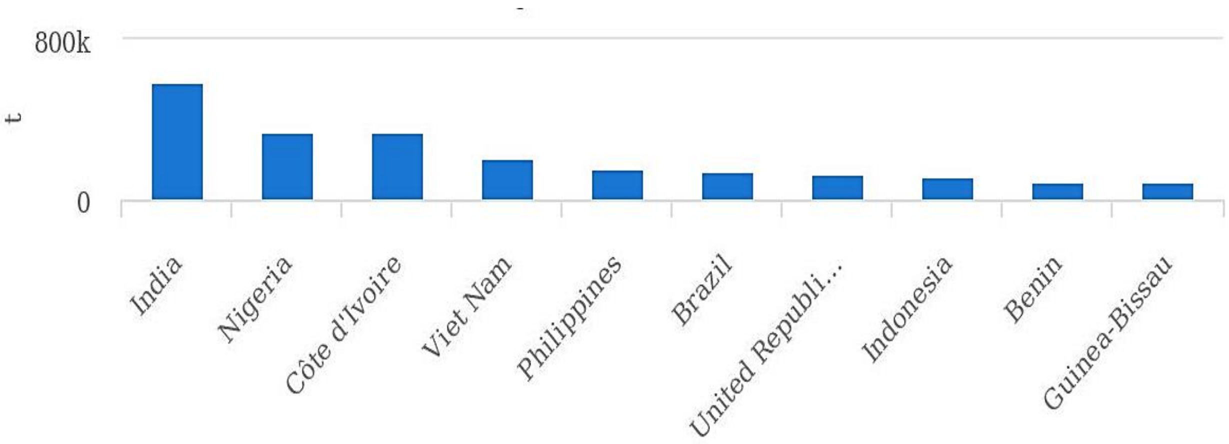


**Figure 1.** Top 10 producers of Cashew nuts between 1994 and 2021. Source: FAOSTAT (2023)

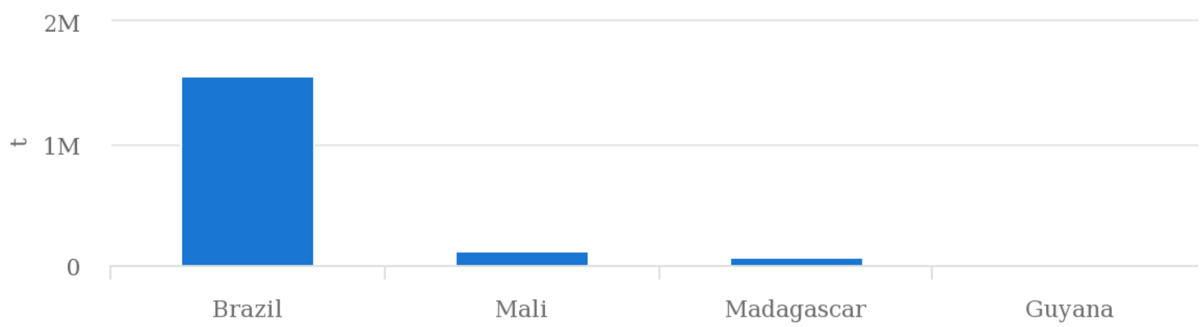


**Figure 2.** Top producers of Cashew apple between 1994 and 2021. Source: FAOSTAT 2023

**Nutritional Composition of Cashew Apple**

Cashew apple has a high nutritional value, containing crude protein, crude fat, crude fiber, and minerals and vitamins such as calcium, magnesium, potassium, and vitamin C (Akyereko *et al*., 2023; Sahie *et al*., 2023). The composition of cashew apple varies on factors such as geographical differences, processing factor, agronomic practises, and stage of ripeness - with mature fruit having higher nutrient content than immature fruit (Aidoo *et al*., 2022).

Table 1 shows the proximate composition of cashew apple. The average Dry matter (DM), Crude protein (CP), Crude fibre (CF), Ether extract (EE), Ash, and Nitrogen free extract (NFE) of the five (6) studies are 88.38, 10.52, 6.18, 7.58, 3.05, and 71.88 respectively.

From the studies, it can be concluded that cashew apple are a rich source of energy (Dakuyo *et al*., 2022), making it a primary source of energy for livestock (Akande *et al*., 2015). Studies have shown that the energy content of cashew apple ranges from 75 to 88% of the total dry matter (DM) content (Okpanachi *et al*., 2016b; Joseph *et al*., 2020; Cruz Reina *et al*., 2022). Additionally, the metabolizable energy (ME) content of cashew apple has been reported to range from 7.0 to 8.5 MJ/kg DM (Oliveira *et al*., 2020). Ahaotu and Ihekoronye (2019) reported a digestible energy of 3343.84 Kcal/kg while the average metabolizable energy of the studies was 3489.42 Kcal/kgDM. These values indicate that cashew apple can provide a significant amount of energy to livestock, which can contribute to improved animal growth and productivity.

Cashew apple contain a significant amount of protein (Dakuyo *et al*., 2022), ranging from 3.54% to 7.04% on a dry matter basis (Fanimo *et al*., 2003; Ogunjobi and Ogunwolu, 2010; Rico *et al*., 2015). From Table 1, the protein composition of cashew apple ranged up to 18.70 %. The protein content of cashew apple is comparable to that of other tropical fruits such as mango and pineapple (Rico *et al*., 2015).

Cashew apple is also a good source of dietary fiber (Guedes-Oliveira *et al*., 2016; Aluko *et al*., 2023 Akyereko *et al*., 2023), containing 5.5% to 12.5% on a dry matter basis (Rico *et al*., 2015; Kaprasob *et al*., 2018). The fiber in cashew apple is mainly composed of cellulose and hemicellulose, which are highly digestible by ruminants (Jeyavishnu *et al*., 2021; An *et al*., 2022; Cruz Reina *et al*., 2022; Thiviya *et al*., 2022).

Cashew apple are rich in minerals and vitamins such as calcium, magnesium, potassium, and vitamin C (Akyereko *et al*., 2023). The mineral content of cashew apple ranges from 0.51% to 2.07% on a dry matter basis, with calcium and magnesium being the most abundant minerals (Rico *et al*., 2015; Dedehou *et al*., 2016). Vitamin C content of cashew apple juice was reported to be 70 mg/100 mL by (Cruz Reina *et al.* 2022).

**Antinutritional Composition of Cashew Apple**

Okpanachi *et al.* (2016a) and Okpanachi *et al.* (2016b) found that cashew apple contains antinutritional components such as phytate, oxalate, tannin, flavonoids, and saponin. Sun-dried red cashew pulp had 0.0701% saponin, 0.0877% tannin, 0.0438% flavonoid, 0.3661% phytate, and 0.0327% oxalate, whereas sun-dried yellow cashew pulp contained 0.1568% saponin, 0.0621% tannin, 0.0767% flavonoid, 0.3159% phytate, and 0.0287% oxalate. Cashew apple also contain up to 0.2 to 0.4% tannins, a group of compounds that provide the caustic, bitter flavor and make processing difficult (Dao *et al.*, 2021b).

Phytic acid is found in the outer layer or skin of cashew apple (Gupta *et al.*, 2013). It can bind to minerals like calcium, magnesium, and zinc, reducing their absorption in the digestive tract. Tannins are compounds that can interfere with protein digestion and nutrient absorption (Hassan *et al.*, 2020; Samtiya *et al.*, 2020). They may also impart a bitter taste to some cashew varieties (Dao *et al.*, 2021b; Dheeraj *et al.*, 2023). Roasting or blanching cashew apple can help reduce tannin levels (Dao *et al.*, 2021b).

Most of these antinutritional contents are decreased or removed by standard processing procedures such as roasting and blanching (Samtiya *et al.*, 2020; Anaemene and Fadupin, 2022). Furthermore, the nutritional advantages of cashew apple, such as their high value of energy, fats, protein, and necessary minerals, often outweigh the potential negatives of these antinutritional aspects.

Phytochemicals in cashew apple can significantly affect livestock performance by reducing the bioavailability of essential nutrients and interfering with metabolic processes. For example, phytates and oxalates bind minerals like calcium, magnesium, and zinc, leading to deficiencies that impair bone health, enzyme activity, and overall growth in livestock (Fukushima *et al.*, 2020). These effects can result in reduced feed efficiency, slower weight gain, and lower productivity in animals.

To mitigate these challenges, various processing techniques have been developed. Soaking and fermentation can reduce the levels of phytates, improving mineral bioavailability (Fukushima *et al.*, 2020). Roasting and blanching effectively lower tannin content, enhancing protein digestibility and palatability Anaemene and Fadupin, 2022). Incorporating enzyme supplementation, such as phytase, into animal diets can further mitigate the impact of phytates (Samtiya *et al.*, 2020). Additionally, blending cashew apple with other feed ingredients can dilute antinutritional components while optimizing the overall nutrient profile of the diet.

These strategies, when applied effectively, enable the safe and productive use of cashew apple as a supplementary feed resource for livestock, maximizing its nutritional benefits while minimizing adverse effects.

**Table 1.** Proximate Composition of Cashew Apple

| Parameters (%) | A | B | C | D* | E** | F | Average |
|---|---|---|---|---|---|---|---|
| **Dry matter** | - | 86.90 | 81.00 | 88.78 | 89.20 | 96.00 | 88.38 |
| **Crude protein** | 18.70 | 7.76 | 8.60 | 13.82 | 16.96 | 5.45 | 10.52 |
| **Crude fibre** | 8.40 | 6.65 | 3.80 | 6.71 | 7.08 | 6.65 | 6.18 |
| **Ether extract** | 2.40 | 3.90 | 9.96 | 10.62 | 10.41 | 3.00 | 7.58 |
| **Ash** | 5.40 | 3.62 | 3.80 | 2.85 | 2.48 | 2.50 | 3.05 |
| **Nitrogen free extract** | 65.10 | 78.07 | 73.84 | 66.00 | 63.07 | 78.40 | 71.88 |
| **Digestible energy (Kcal/kgDM)** | - | - | 3343.84 | - | - | - | - |
| **Metabolizable energy (Kcal/kgDM)** | 3184.33 | 3358.89 | 3731.51 | 3701.36 | 3697.10 | 3212.17 | 3489.42 |

* = Yellow cashew apple; ** = Red cashew apple; A – Fanimo *et al.* (2003); B – Castillo and Gerpacio (2005); C – Ahaotu and Ihekoronye (2019); D - Okpanachi *et al.* (2016a); E – Okpanachi *et al.* (2016b); F - Boateng *et al.* (2021)

**Processing Cashew apple as a Livestock Feed Resource**

Cashew apple are either picked directly off the trees or gathered from the ground beneath the trees (Dakuyo *et al.*, 2022; Sahie *et al.*, 2023). In order to prevent damage, the nuts and apples are properly separated (Sahie *et al.*, 2023). Various processing techniques have been developed to overcome the challenges associated with the use of cashew apple as a feed resource for livestock. These techniques include dehydration, ensiling, and blending with other feed ingredients.

1. **Dehydration:** Dehydration is a process that removes moisture (Riaz *et al.*, 2023) from cashew apple, increasing their shelf life and preserving

their nutritional quality. Studies have shown that dried cashew apple retain a significant amount of protein, fiber, and mineral content, making it a viable alternative to fresh cashew apple as a feed resource (Oliveira *et al*., 2020).

2. **Ensiling:** Ensiling is a process that involves fermenting cashew apple under anaerobic conditions to preserve their nutritional quality and increase their shelf life (Sahie *et al*., 2023). Studies have shown that ensiled cashew apple retain a significant amount of their protein, fiber, and mineral content, making them a viable alternative to fresh cashew apple as a feed resource for ruminants (Tai *et al*., 2020; Costa *et al*., 2021).
3. **Blending with Other Feed Ingredients:** Cashew apple can be blended with other feed ingredients to create a balanced diet for livestock. For example, cashew apple meal can be mixed with other ingredients such as rice bran and urea to increase the protein content of the feed (Bain *et al*., 2016; Thanh Huyen *et al*., 2020).

## Feeding Strategies for Cashew apple

This depends largely on the form of cashew apple and the intended livestock species to be fed. The following are some feeding strategies that have been used for the incorporation of cashew apple in livestock feed:

1. **Fresh cashew apple:** Fresh cashew apple can be fed directly to ruminants, such as cattle, goats, and sheep, either as a sole feed or as a supplement to the basal diet. In one study, fresh cashew apple were offered *ad libitum* to West African Dwarf goats, resulting in increased feed intake and weight gain (Oluwatosin *et al*., 2021). The observed result of Oluwatosin *et al.* (2021) agreed with the report of Preethi *et al.* (2019). However, it is important to note that fresh cashew apple have a short shelf life, and must be fed within a few days of harvest to avoid spoilage and nutrient losses.
2. **Dried cashew apple:** Drying cashew apple can increase their shelf life and nutrient density, making them a more convenient and economical feed option. Dried cashew apple were included in the diets of rabbits, resulting in improved growth performance and feed efficiency (Gomes *et al*., 2018), it was also offered to albino rats to evaluate its effect on growth performance and the internal organs (Boateng *et al*., 2021). Dried cashew apple can also be ground and mixed with other feed ingredients to formulate a complete diet for livestock.
3. **Silage:** Cashew apple can be ensiled to preserve their nutrients and extend their shelf life. In a study conducted by Tai *et al.* (2020), cashew apple silage was included in the diets of dairy cows, resulting in improved milk yield and milk fat content. However, the ensiling process requires proper management to ensure the production of high-quality silage, and the resulting silage must be stored under appropriate conditions to prevent spoilage.
4. **Juice and pomace:** Cashew apple juice and pomace can also be used as feed ingredients. Tumbagahon (2019) included cashew apple juice residue in the diets of broiler chickens, resulting in improved feed conversion efficiency and carcass yield. Cashew apple pomace residue, which is the solid remaining after juice extraction, can be used as a source of fiber and energy in livestock diets (Preethi *et al*., 2021). However, the use of juice and pomace may be limited by their high moisture content and potential for spoilage.

## Feeding Cashew Apple to Animals

Because of the nutritional content of cashew apple, its having the potential to be used as animal feed (Aluko *et al* 2023). However, its use in animal feed remains restricted due to many obstacles related with processing, preservation, and storage (Dimoso *et al*., 2022). Nonetheless, several research have found that include cashew apple in animal diet can have a number of advantages.

Studies have shown that cashew apple can be incorporated into the diets of different livestock species, including cattle, sheep, goats, pigs, etc. The inclusion level varies depending on the species, stage of growth, and physiological status of the animal. In a study by Araújo *et al.* (2022), the inclusion of dehydr ated cashew apple up to 33% level in the concentrate mixture improved the feed efficiency of sheep, and there was no adverse effect on their growth rate and nutrient utilization.

Similarly, Okpanachi *et al.* (2016a) observed that goats fed with cashew apple meal-based diets had higher dry matter intake and growth performance compared to those on a control diet. The authors reported that cashew apple meal can be included up to 30% level in the diet of goats without any adverse effects on their performance.

The high fiber content of cashew apple makes it an excellent source of roughage in animal diets. In addition, it has a significant amount of minerals, such as calcium, phosphorus, and potassium, which are essential for animal growth and development (Bhakyaraj and Singaravadive, 2012). Cashew apple also contain antioxidants, such as vitamin C, and flavonoids, which can improve the immune status and overall health of the animals (Salehi *et al.,* 2020).

However, its utilization is still limited due to challenges associated with processing, preservation, and storage.

## Effect on Growth Performance

Several research have been carried out to determine the effect of including cashew apple in cattle diets on growth performance. Oliveira *et al.* (2020) investigated the usage of cashew apple meal to substitute maize in dairy cow diets. The study revealed that substituting maize with cashew apple meal had no significant effect on milk output or composition. Cows given the cashew apple meal diet, on the other hand, consumed less dry matter and gained less body weight than cows on the corn diet.

Boateng *et al.* (2021) assessed the effect of dried cashew apple meal on the growth performance of albino rats. The diets were formulated to have up to 15% inclusion level of dried cashew apple meal and there were no differences between diets with regards to growth performance. The dried cashew apple meal was determined to be beneficial in monogastric feeding and may be introduced at a rate of up to 15% of the diet.

The study of Fanimo *et al.* (2003) on the effect of cashew apple on the growth performance of growing rabbits concluded that up cashew apple can be included in the diet of growing rabbits up to 30% inclusion level because rabbits fed diets with 20 and 30% cashew apple gained more weight when compared to those on the control diet.

Tai *et al.* (2020) evaluated the use of cashew apple meal as a replacement for corn in the diet of fattening cattle. The study found that incorporating cashew apple with maize grain, corn and maize cob up to 26.25% did not significantly affect final body weight and average daily gain in fattening cattle.

Araújo *et al.* (2022) evaluated the effects of dehydrated cashew apple in different grinding sizes to sheep on growth performance. The study found that feeding sheep up to 33% cashew apple had no influence on the voluntary intake and the growth performance.

A study conducted by Aghili *et al.* (2020) investigated the effect of cashew apple pomace inclusion in the diet of broiler chickens. The study found that the inclusion of cashew apple pomace in the diet of broiler chickens up to 12% significantly improved feed conversion ratio and body weight gain, indicating that cashew apple pomace can be used as a cost-effective feed ingredient in broiler chicken diets.

Similarly, a study conducted by Gomes *et al.* (2018) evaluated the effect of cashew apple pomace on growth performance and carcass characteristics of rabbits. The study found that the inclusion of cashew apple pomace in the diet improved feed conversion ratio, body weight gain, and carcass yield, suggesting that cashew apple pomace can be a valuable feed resource for rabbits.

## Effect on Haematology and Serum Biochemistry

The incorporation of cashew apple into animal feeds has demonstrated an effect on hematological and serum biochemical markers. Several studies have evaluated the effect of cashew apple on haematology and serum biochemistry in livestock.

A study by Yusuf and Aliyu-Paiko, (2020). investigated the effects of feeding varying levels of dried cashew apple meal on haematological parameters and serum biochemistry in broiler chickens. The results showed that the inclusion of cashew apple meal in the diet had no significant effect on haematological parameters, except for a decrease in white blood cell counts at higher inclusion levels. However, there was a significant increase in serum total protein and albumin levels, indicating the potential of cashew apple as a protein source in broiler chicken's diets.

In a study by Okpanachi *et al.* (2019), the effects of feeding cashew apple pomace on haematological and serum biochemical parameters in West African dwarf goats were investigated. The results showed that there was no significant difference in haematological parameters between the control and treatment groups, even up to 30% inclusion level of cashew apple. However, there was a significant increase in serum glucose, total protein, and albumin levels in the treatment group, indicating the potential of cashew apple pomace as a source of energy and protein for goats.

Oyewole *et al.* (2017) reported that the inclusion of cashew apple meal in the diet of broiler chickens results into the haematological parameters and serum biochemical indices falling within the normal range reported for healthy broiler chickens, indicating that cashew apple is adequate in minerals and vitamins to support optimal haematopoiesis in broiler chickens.

Finally, the inclusion of cashew apple in livestock diets appears to have a positive effect on haematology and serum biochemistry parameters. However, further research is needed to fully understand the impact of cashew apple on livestock health and performance.

The observed changes in haematological and serum biochemical parameters following the inclusion of cashew apple in livestock diets can be attributed to its nutrient composition and the presence of bioactive compounds. For instance, the significant increase in serum total protein and albumin levels, as seen in studies on broiler chickens (Oyewole *et al*., 2017; Yusuf and Aliyu-Paiko, 2020). and West African dwarf goats (Okpanachi *et al*., 2019), suggests that cashew apple provides a readily available protein source. This enhanced protein availability likely supports liver function and protein synthesis, reflected in elevated serum protein levels in animals consuming cashew apple.

The carbohydrate-rich composition of cashew apple contributes to its role as an energy source. This is evident from the increased serum glucose levels observed in goats fed cashew apple pomace, highlighting its potential to support energy-dependent physiological processes and metabolic activities. These compounds could influence immune responses, as suggested by changes in white blood cell counts at higher inclusion levels, either through direct effects on immune cells or indirectly by reducing systemic inflammation.

Cashew apple also appears to support optimal haematopoiesis due to its mineral and vitamin content. Minerals like iron and vitamins such as vitamin C may play crucial roles in red blood cell production and overall blood health, maintaining haematological parameters within normal ranges. However, at higher inclusion levels, the antinutritional effects of these compounds may disrupt nutrient absorption, as reflected in reduced white blood cell counts.

Overall, the effects of cashew apple on haematological and biochemical parameters seem to result from its nutrient density and the physiological impact of its bioactive compounds. These findings underscore the potential of cashew apple as a functional feed ingredient, though further research is needed to optimize its inclusion levels and fully understand its impact on livestock health and performance.

### Effect on Carcass Characteristics

Several studies have been conducted to investigate the effect of cashew apple in livestock diet on carcass characteristics. The results of these studies have been mixed, with some showing positive effects on carcass quality, while others have found no significant difference.

Fanimo *et al.* (2003) investigated the effects of cashew apple inclusion in the diet of growing rabbits on carcass characteristics. The study found that the inclusion of cashew apple pulp up to 30% resulted in improved relative carcass traits in growing rabbits.

Moreover, in another study conducted by Yisa and Longe, (2020), the inclusion of cashew apple pulp in the diet of broiler chickens was shown to have no significant effect on the carcass characteristics of the birds. The study, however, reported that the inclusion of cashew apple pulp up to 20% in the diet significantly increased the thigh yield of the broiler chickens.

### Challenges Associated with Cashew Apple as a Feed Supplement

Cashew apple are a valuable resource with high nutritional value that can be used as a feedstuff for livestock. However, using it as a feed resource presents a number of obstacles that must be solved in order to fully realize their potential. These problems include limited supply, short shelf life, and high moisture content.

1. **Limited Availability:** The cashew apple's seasonality (Akyereko *et al*., 2022) limits its availability as a feed resource; depending on the region, the harvest season lasts from January to May each year. This may reduce the amount of cashew apples available for feeding animals. Additionally, the limited harvesting season of cashew apples further restricts their supply (Talasila and Shaik, 2015; Lorenzoni *et al*., 2018). As a result, plans must be created to expand the cashew apple's supply as a livestock feed source.
2. **Short Shelf Life:** After harvest, cashew apples usually don't stay around for more than two or three days (Talasila and Shaik, 2013; Nwosu *et al*., 2016; Oliveira *et al*., 2020). This is because cashew apples are prone to fermenting and spoiling because of their high moisture content. Therefore, it's critical to create plans to maintain cashew apples' nutritional value and increase their shelf life.
3. **High Moisture Content**: Cashew apple have high moisture content (Singh *et al*., 2019; Olalusi *et al*., 2020), ranging from 77% to 88%, depending on the stage of ripeness (Rico *et al*., 2015; Aidoo *et al*., 2022). High moisture content can lead to spoilage and fermentation, making it difficult to store cashew apple for an extended period of time. Additionally, high moisture content can result in nutrient loss and reduced palatability of cashew apple (Gawankar *et al*., 2018). Therefore, strategies to reduce the moisture content of cashew apple need to be developed to enhance their storability and nutritional value. Addressing these challenges will enable the utilization of cashew apple as a feedstuff, thereby enhancing the sustainability and profitability of livestock production, and value addition to the cashew production chain.

## Recommendations for Future Research

Future research should focus on addressing the existing challenges associated with cashew apple utilization in livestock feed and exploring its broader applications. Studies should investigate optimal inclusion levels of cashew apple for different livestock species and production stages, considering its nutrient composition and potential antinutritional factors. Research into innovative preservation and processing methods, such as fermentation, dehydration, and ensiling, is crucial to enhance the shelf life and nutritional quality of cashew apple while minimizing nutrient losses. Additionally, more in-depth exploration of its bioactive compounds and their potential health-promoting effects on livestock is warranted, particularly regarding immunity, gut health, and overall productivity.

On a practical level, efforts should be made to integrate cashew apple processing into the cashew value chain. Governments and agricultural stakeholders could invest in infrastructure for large-scale processing and preservation facilities to reduce post-harvest losses. Farmer education and training programs can highlight the economic and nutritional benefits of utilizing cashew apple as a feed resource. Furthermore, partnerships between researchers, policymakers, and the private sector can foster the development of marketable cashew apple-based feed products, creating new economic opportunities for cashew-producing regions.

Finally, incentivizing the adoption of cashew apple as a feed ingredient through subsidies or grants for feed manufacturers and farmers can accelerate its integration into livestock production systems. By addressing these practical and research-based gaps, the potential of cashew apple as a sustainable, cost-effective feedstuff can be fully realized, contributing to improved livestock performance and food security.

## Conclusion

Cashew apple have shown great potential as a commercial feedstuff for livestock. They are rich in nutrients such as energy, fiber, protein, minerals, and vitamins, which can contribute to improved animal growth, health, and productivity. Additionally, the use of cashew apple as feed can provide a valuable source of income for farmers and improve the sustainability of cashew production systems.

However, there are still challenges associated with the processing, preservation, and utilization of cashew apple as feed. Addressing these challenges through research, innovation, and education can help to unlock the full potential of cashew apple as a valuable feed resource for livestock production. Furthermore, the use of cashew apple as feed can contribute to the development of more sustainable and diversified livestock production systems, which can help to improve the livelihoods of small-scale farmers and ensure food security for growing population.

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