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Cashew (*Anacardium Occidentale* L.) Products and Byproducts: Nutrient Constituents and Nutritional Benefits in Livestock Diets

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ABSTRACT

Inadequate availability, price hikes, and rivalry between food and feed means there is an incessant request for unconventional feedstuffs for livestock. As a result, other sustainable feed material needs to be explored. Cashew (Anacardium occidentale L.) is a tropical tree known for its apple and nut. Cashew apple, cashew kernel waste meal, and cashew nut shell liquid residue have the potential as a valuable ingredient in livestock feeds and have gained increasing attention. They are becoming more and more valuable ingredients in livestock diets, owing to their availability. Systematic utilization has been shown to drive down feed costs, enhance animal nutrition and productivity making them suitable for incorporation into animal diets. However, available research output on the use of cashew apple, cashew kernel waste meal, and cashew nut shell liquid residue in livestock feed is lacking in consistency among quantified nutritive benefits. This review encompasses a comprehensive analysis of the nutrient composition of cashew products, byproducts, and their potential uses as alternative ingredients in livestock diets.

Kaju (*Anacardium Occidentale* L.) Ürünleri ve Yan Ürünleri: Hayvancılık Diyetlerinde Besin Bileşenleri ve Besinsel Faydaları

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ÖZ

Yetersiz bulunabilirlik, fiyat artışları ve gıda ile yem arasındaki rekabet, besi hayvanlarına yönelik alışılmadık yem maddelerine yönelik sürekli bir talebin olduğu anlamına geliyor. Sonuç olarak, diğer sürdürülebilir yem materyallerinin araştırılması gerekmektedir. Kaju (Anacardium occidentale L.), elması ve ceviziyle tanınan tropik bir ağaçtır. Kaju elması, kaju çekirdeği atık küspesi ve kaju fıstığı kabuğu sıvı kalıntısı, hayvan yemlerinde değerli bir bileşen olma potansiyeline sahiptir ve giderek daha fazla ilgi görmektedir. Bulunabilirlikleri nedeniyle hayvan beslenmesinde giderek daha değerli bileşenler haline geliyorlar. Sistematik kullanımın yem maliyetlerini düşürdüğü, hayvan beslenmesini ve üretkenliğini arttırdığı ve onları hayvan diyetlerine dahil edilmeye uygun hale getirdiği gösterilmiştir. Bununla birlikte, kaju elması, kaju çekirdeği atık küspesi ve kaju fıstığı kabuğu sıvı kalıntısının hayvan yemlerinde kullanımına ilişkin mevcut araştırma çıktıları, niceliksel besleyici

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faydalar arasında tutarlılık açısından eksiktir. Bu inceleme, kaju ürünlerinin besin kompozisyonu, yan ürünleri ve bunların hayvancılık beslenmesinde alternatif bileşenler olarak potansiyel kullanımlarının kapsamlı bir analizini kapsamaktadır.

Introduction

The cost of livestock feed is one of the factors that have led to the elevated cost of production (Oyewole et al., 2013). According to Oladunjoye et al. (2004), the high price of maize grains makes it challenging for farmers to afford the feedstuff. In addition, the demand for maize grains by both man and animals for cereals, pulses, and oil seeds is primarily responsible for the increasing price of livestock feed (Oladunjoye et al., 2004). The research on substitute feed ingredients is the key to solving this problem(Edame et al., 2011). However, such substitutes ought to be more affordable and nutritious as orthodox feedstuff if not more than conventional protein and energy sources (Oladunjoye et al. 2004). Drought-resistant crops or tree products have to be explored as substitute feedstuffs (Amata, 2014). Since feed costs make up between for 60-70% of the overall cost of production, significant efforts are being made to identify potential substitutes (Mitchell, 2008). Crop wastes and residues, as well as agro-industrial byproducts such as maize offal (Nnenna et al., 2006), cassava peel meal (Ojediran et al., 2022a; Salami and Odunsi, 2003), palm kernel cake (Ojediran et al., 2022b), biscuit waste dough (Ojediran et al., 2019; Ojediran, et al., 2020), and rice offal (Makinde et al., 2014), had been explored. According to Fanimo et al. (2007), there is considerable untapped potential for livestock feedstuffs in many developing countries, cashew byproducts are one among them.

Cashew (*Anacardium occidentale*) is the third most produced edible nut in the world and is a major cash crop (Kolliesuah et al., 2020). The edible portion is divided into two parts: the cashew nut (the kernel and the true fruit), and the cashew apple, an enlarged peduncle, also called a false fruit usually brightly colored. The cashew tree is now widely grown for its kernel, fruit, nut shell liquid, and other products.

Global Cashew Production

The expansion of the cultivated area, which increased from 1,963,000 ha in 1992 to more than 5,300,000 ha in 2011 is more responsible for the recent increase in cashew production than the almost double increase of productivity per hectare from 475 to 805 kg/ha over the same reference period. According to Bavier (2014), the Ivory Coast was the top nut exporter from Africa in 2014 as a result of the country's rapid increase in cashew production. The cashew nut sector is experiencing discontent due to fluctuating world market prices, poor labor conditions, and insufficient wages for local harvesting (Lamble, 2013; Wilson, 2015). In 2020, 4.1 million tons of cashew nuts were produced in 38 countries around the world, mostly in developing areas (FAOSTAT, 2021a).

In 2021, the global population produced 3.7 million tonnes of cashew nuts (as the kernel), with Ivory Coast and India accounting for 43% of the total output, and 1.36 million tonnes of cashew apples, with Brazil accounting for 82% of the production (FAOSTAT, 2021b).

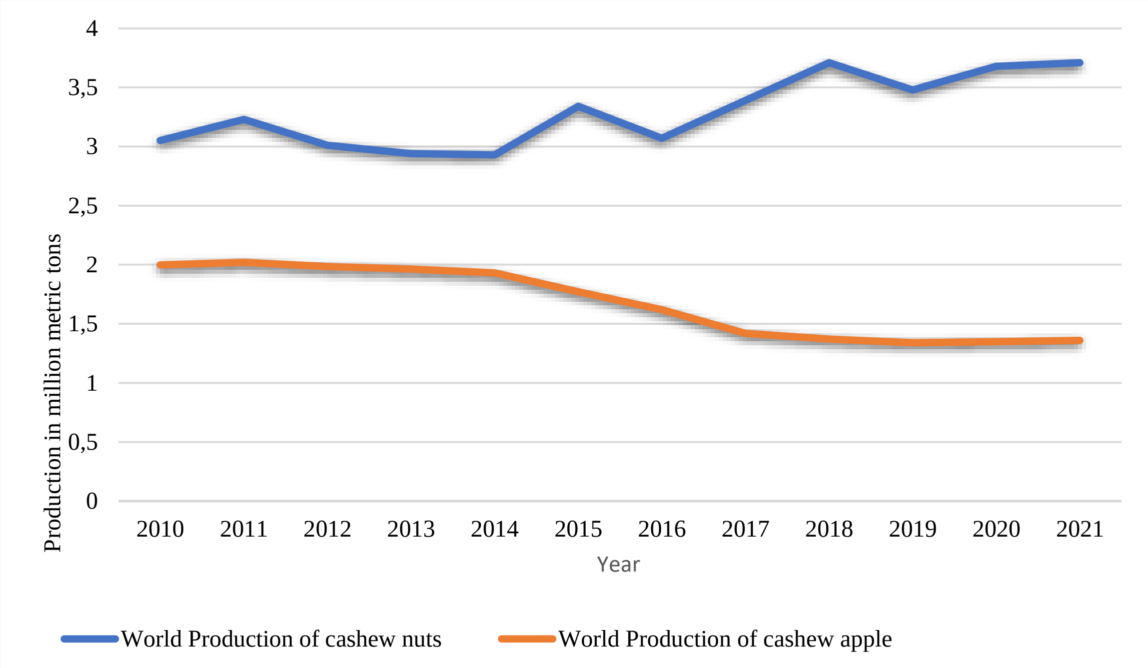

Figure 1. Production of cashew nuts and cashew apples worldwide from 2010 to 2021 (in million metric tons) (FAOSTAT, 2023)

Şekil 1. *2010'dan 2021'e kadar dünya çapında kaju fıstığı ve kaju elması üretimi (milyon metrik ton olarak) (FAOSTAT, 2023)*

Vietnam, India, Cote d'Ivoire, Brazil, Nigeria, Indonesia, Philippines, United Republic of Tanzania, Benin, and Guinea-Bissau were the top 10 producers of cashew nuts from 2017 to 2021. Brazil, Mali, Madagascar, and Guyana were the top 4 countries for cashew apple production from 2010 to 2021 (FAOSTAT, 2021b).

The Cashew Fruit

A medium-sized tropical tree known as the cashew is cultivated primarily for its fruit: cashew nuts, and cashew apple (sometimes called a pseudocarp). A delicious, sweet flavor can be found in the large, pulpy, and juicy section of the cashew apple. Ahaotu and Ihekoronye (2018) assert that cashew is a rich source of vitamins, minerals, and other nutrients. It can be grown in a range of soil types and can tolerate a variety of rainfall patterns (Odunsi, 2002).

The lower, heart-shaped, or conical section of the cashew apple is where the nut is jointed. The kidney- or c-shaped cashew nut (seed) hangs at the bottom of the apple. The curved fruit, which resembles a huge thick bean but is not a genuine nut, can grow to a length of more than 2.5 cm (1 inch). By the third or fourth year, the tree begins to produce fruit, and by the seventh year, it has reached its full yield (Morton, 1987)

After three years, cashew trees usually start to generate fruit, and after seven or eight years, they can start to yield their full potential. The cashew tree's economic life span is 20 to 25 years, after which time yields start to decline. The kernel, which is covered by a thicker outer shell and a thin skin (testa), is the section of the nut that is often referred to as cashew. The thin skin has an acidic oil called cashew nut shell liquid (CNSL), a vital byproduct of the manufacture of cashew nuts with several applications. According to Sogunle (2005), the pericarp of the nut is made up of two shells separated by a resinous layer that contains an acid fluid that corrosive effect on the skin and produces blisters if the shells are broken manually. Cashew is the third most-produced edible nut in the world (Kolliesuah et al., 2020). According to Adejo et al. (2011), a mature cashew tree produces 7-11kg of nuts on average annually.

Cashew products

According to Olife et al. (2013), the main cashew products include dried cashew nuts, ready-to-eat cashew kernels, cashew nut shell liquid (CNSL), cashew juice, cashew apple jam, cashew apple candy, and cashew apple wine. The fat-soluble vitamins A, D, and K, as well as minerals like calcium (Ca), phosphorus (P), and iron (Fe), are all contained in the nuts of the ripe cashew apple and are vital for the body's healthy growth (Akanni and Adams, 2011). The mature cashew apple is also tasty and high in vitamin C and sugar.

Cashew byproducts

Different authors have reported the use of cashew byproducts in livestock diets. Cashew apple juice and liquor residue, the waste following juice extracted from cashew apples can be used as a source of feed for poultry, pigs, goats, and cattle (Kinh et al, 1997, Fanimo et al., 2003, Okpanachi et al., 2016b, Joseph et al., 2020). Discarded cashew kernel meal which is usually wasted as damaged or burned kernels that do not meet export requirement standards can be used for animal feeds (Odunsi, 2002, Usman et al., 2016, Ojediran et al., 2022c) and cashew nut shell cake, the de-oiled cashew shell which is a byproduct of cashew nut shell liquid production. These byproducts can be used as feedstuff for poultry, pig, and ruminants.

Cashew apple juice and liquor residue

Cashew apples are frequently described as the false fruit of the cashew tree. It is a tropical ‘fruit’, which is discarded as manure after picking the nut attached to it. Although the majority of cultivation is focused on producing the most valuable, the cashew apple is utilized locally in beverages, jams, and jellies. The true fruit of the cashew tree, the cashew nut, is carried by a protruding stalk known botanically as the cashew apple. The mature cashew apple is usually discarded during the cashew nut harvest because it quickly starts to ferment and decompose after falling from the tree. However, several food products, such as pectin, juices, alcoholic beverages, vinegar, syrups, and jams, can be made from cashew apples. Antioxidants and vitamin C levels are also elevated (Oliveira et al., 2020). In addition to these products, research has shown that juice residue has the potential to serve as a source of carotenoids for natural food colorants or dietary supplements (Abreu et al., 2013). The fibrous residues left behind from the manufacturing process of cashew apple juice can also be further refined to produce animal feed (Gomes et al., 2018). A small amount of cashew apples are eaten directly in orchards in cashew-growing regions or converted into artisanal food products for local consumption; nonetheless, commercial utilization of the cashew apple is still very rare in the majority of cashew-growing nations.

Cashew apples have been consumed by animals in regions where it has been grown for a very long period of time since free-range animals like chickens, pigs, goats, sheep, and cattle have always fed voluntarily during the harvest season. Compared to orange juice, cashew apples have vitamin C levels that are up to six times higher, as well as other phytochemicals (carotenoids, flavonoids, anacardic acid, and tannins), vitamins, minerals, and dietary fibers, according to Das and Arora (2017). The nutrient composition demonstrates the potential to be created as a functional food, generating economic value and minimizing waste (Prakoso & Mubarok 2021).

According to Akyereko et al. (2022), the cashew apple makes up around 90% of the weight of the cashew fruit, which results in the production of about 36.9 million tons of cashew apples. This false fruit is hardly ever used and is typically seen as a waste product (Tamiello-Rosa et al. 2019). Only 1.36 million tons, or 3.5% of the available product, are being utilized in commercial production (FAOSTAT, 2021b). As seen in Brazil (Pinho et al. 2011), the peduncle is primarily used for juice and beverage preparation.

Brazil reportedly uses cashew apples at a rate of 15% (Luciano et al., 2011). The bulk of cashew apples harvested in Brazil are converted into cashew apple juice, which is both extensively utilized locally and abroad. Additionally, cashew apples can be processed into candy and cajuna, a clarified juice, or marketed as fresh fruit. A small portion of cashew apples are utilized in India to make juices, sweets, jams, pickles, and chutneys. In Goa, cashew apples are also used to make the alcoholic beverage 'feni' (Attri, 2009; Lowor et al., 2016; Prasertsri & Leelayuwat, 2017).

The majority of cashew apple residue is generated in the processing sector (Akanro et al., 2022). This waste can be used as a source of feed for poultry and dairy farms (Okpanachi et al., 2016b). Following juice extraction, the cellulose-rich processing unit waste can be converted into high-nutrient cattle and poultry feed in either a wet or dry format. Cashew apples can be an excellent potential feed for chickens or cattle due to their high dry matter (22.5%), protein content (13.7%), and low crude protein (11.8) content (Damasceno et al., 2008).

Cashew apple residue has been described by different authors with different names. Joseph et al., (2020) described it as cashew pulp waste, cashew pulp meal by Okpanachi et al., (2016a). Fanimo et al., (2003) and Kinh et al. (1997) described it as cashew apple waste.

Cashew kernel waste

The major commercial product of the cashew tree is the raw cashew nut, however, the yield of the cashew apple is eight to ten times greater. Nuts are transported unprocessed or after being treated. The kernel of raw cashew nuts must be removed through several processing procedures. The outer shells of raw cashew nuts undergo thermal treatment in the first phase to make them brittle. Steaming, roasting, and soaking raw cashew nuts in a hot oil bath are the three basic techniques (Mohod et al., 2011). Cashew nuts are shelled in the second process, which involves separating the kernels from the outer shells. This procedure may be carried out manually, mechanically, or automatically. The kernel must then be dried before the testa can be peeled off. The byproducts of the cashew processing industries, the testa and cashew shell, can undergo additional processing to produce a variety of products. They can also be combined with other nuts. The byproduct cashew nut shell liquid (CNSL), which has industrial and medicinal uses, is produced during the processing of the raw nuts. The skin of the nut may be collected and utilized to tan hides because it contains a lot of tannins. Cashew kernels have to be carefully removed from their toxic shells to avoid being contaminated by the toxic compound encased in the mesocarp. The kernels are then removed from the nut and roasted to eliminate any leftover toxins (Orwa et al., 2009).

The nut is processed for its edible kernel. According to Rico et al. (2015), the cashew (*Anacardium occidentale* L.) nut ranks third in the global production of edible nuts traded internationally. In the industrial setting, between 30 and 35 % of cashew kernel meal is usually wasted as damaged or burned kernels at some point in the processing because the grade does not meet export or local requirement standards (Akande & Gbadamosi, 2018). According to Ahaotu and Ihekoronye (2008), using cashew nuts as animal feed will reduce the problem of pollution. According to reports (Odunsi, 2002; Ojewola et al., 2004; Akande et al., 2015), cashew nuts, primarily the rejects, have been used as animal feed.

Cashew nuts can be used in a various forms of spreads, sauces, bars, and beverages as a salty or sweet snack, an ingredient in desserts and savory dishes, or by undergoing additional processing to create cashew butter. Cashew kernels can also be used to make cashew oil.

The kernels are an excellent source of fats, carbohydrates, protein, vitamins, and minerals, making them a nutritious food. The final procedure in processing cashew nuts for confectionary involves either manually or mechanically removing the red testa. These skins can be utilized as feed and may contain bits of broken kernels (Donkoh et al., 2012). 40% of cashew kernels are used in confectionary while 60% are consumed as snacks. When cashew nuts are processed, a liquid known as CNSL is released that has both industrial and medical applications (Azam-Ali and Judge, 2001).

Different authors called it different names, Ojewola et al. (2004) and Fernandes et al. (2016) called it cashew nut meal, Ojediran et al. (2022c) called it cashew reject kernel meal, Odunsi (2002) called it reject cashew kernel meal and Usman et al. (2016) called it cashew nut waste. Agbede et al. (2006) called it defatted cashew nut meal (DCNM) and full-fat cashew nut meal (FCNM).

Cashew nut shell cake

The mesocarp of the cashew contains cashew nut shell liquid (CNSL), often known as cashew oil. Anacardic acid, a salicylic acid analog, and severe skin irritant, constitutes about 70% of CNSL, together with cardol (18%) and cardanol (5%). CNSL, a viscous liquid comprises 20–25% of the weight of raw cashew nuts. According to Telascrêa et al. (2014), Numerous advantageous aspects of CNSL-based polymers include low fading characteristics, water repellency, wear and electrical resistance, solubility in conventional organic solvents, compatibility with a variety of different polymers, and antimicrobial properties. As a result, they are an appropriate raw material for a variety of industrial, chemical, and pharmaceutical applications.

For the automotive industry, CNSL is primarily used in the production of clutch facings and brake linings (Lubi and Tchachil, 2000). Additionally, CNSL is employed in the paint and coatings market, where it could replace raw materials derived from petroleum (Balgude and Sabnis, 2014). Additionally, Sanjeeva et al. (2014) have shown that CNSL has the potential to be used as a biofuel or as an addition to biofuel. Additionally, CNSL is used in a variety of procedures for making plastic, rubber, and adhesives. According to research (Vani et al., 2018), CNSL has the potential to be included in non-toxic insecticides.

CNSL can be extracted from the cashew shell using a variety of techniques. The two most used techniques are extraction in a heated oil bath prior to shelling and mechanical extraction using screw expellers. Tyman et al. (1989) and Das et al. (2004) suggest solvent extraction as well as extraction using pyrolysis as additional methods. The method of extraction determines the chemical composition of CNSL, which could produce CNSL that contains a significant amount of either anarcadic oil or cardanol. The top three CNSL manufacturers are Brazil, India, and Vietnam. Cashew nut shell cake is the de-oiled cashew shell which is a byproduct gotten in the manufacturing process of CNSL. It can be used as a base ingredient for a variety of products. To make briquettes that may be used to burn industrial boilers, shell cake, for instance, can be carbonized and combined with a binder (Sawadogo et al., 2018). Additionally, shell cake can be converted into vermiculite, another substance utilized in hydroponics and hydroculture (United Nations, 2021).

Other cashew products

Cashew tree timber provides excellent furniture, fishing boats, firewood, produce charcoal. Maheswari et al. (2008) reported that adult goats can be fed cashew tree leaves. Cashew gum, sometimes referred to as Anacardium gum, is an exudate that forms on the cashew tree's bark. Among the many industrial uses for cashew gum, which is a complex polysaccharide, are in the food, drug industries (Kumar et al., 2012), and beverage industries (Porto and Cristianini, 2014) as encapsulating, clarifying, and emulsifying agent and pharmaceutical excipient in medicine delivery systems (Ribeiro et al., 2016). Cashew wine is produced in numerous nations throughout Asia and Latin America. It has a pale-yellow color with a 6-12% alcohol content.

Nutrient Composition of Cashew Byproducts

Cashew apple

Cashew apples contain a variety of nutrients, including sugar, tannins, amino acids, tannin, crude fiber and ascorbic acid (vitamin C). Ascorbic acid, a highly rich source of vitamin C, is abundant in cashew apples and is about six times as abundant in them as it is in citrus fruits (40 mg/IOO g). The cashew apple also has soluble sugars, the majority of the soluble sugars are reducing sugars, in addition to vitamin C. The crude fiber content of cashew apples, measured in terms of dry weight, ranges from 15-18%. The phenols, flavonols and tannin found in cashew apples may act as organic antioxidants and play a significant part in the destruction of free radicals. The cashew apple is an excellent source of fiber and vitamin C. Consuming cashew apples may aid in minimizing constipation and Vitamin C deficiency (Bhat, 2008).

Proximate and chemical composition of cashew apple waste

Table 1 shows the proximate and chemical composition of cashew apple waste.

The variances noticed in the proximate and chemical composition can be the result of various methods of processing used, storage methods, and plant cultivars (Bhamare et al., 2016).

Table 1. Proximate and chemical composition of cashew apple waste
Tablo 1. Kaju elması atıklarının proksimate ve kimyasal bileşimi

Proximate Fraction (%)	A	B	C	D
Organic Matter	92.65	-	-	
Crude Protein	19.60	2.1	6.45-11.40	12.60
Ether Extract	2.56	0.68	3.35-11.04	5.14
Crude Fiber	14.64	1.56	8.50-14.2	9.17
Total Ash	7.35	0.64	3.51-6.15	5.88
Acid Insoluble Ash	6.67	-	1.26-1.42	
Nitrogen Free Extract	55.85	-	-	67.21
Calcium	0.29	-	0.12	
Phosphorus	0.43	-	0.38	
Metabolizable Energy (kcal/kg)	47.65	-	-	
Dry matter	-	18.4	18.40-22.50	88.40

A - Bhamare *et al*. (2016), B - Swain *et al*. 2007, C - Swain *et al*. 2014. D – Yisa, 2019

Discarded cashew kernel waste

The proteins found in cashew nuts are equivalent to those found in other nuts like almonds and contain all nine essential amino acids. A lot of acidic amino acids can be found in cashew kernel proteins. Unsaturated fatty acids are prevalent in the fat found in cashew nuts. Oleic acid, followed by linoleic acid, makes up the bulk of the fatty acids in cashew kernel fat. The most predominant saturated fatty acid is stearic acid. Cashew nuts also include numerous amounts of inorganic elements, such as sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc, manganese, selenium, and chlorine, in addition to proteins, lipids, and carbohydrates (Bhat, 2008; Gonçalves et al., 2023) The potassium and phosphorus content in cashew kernels is high. For the maintenance of the human kidney, potassium is recognized to be crucial. The selenium found in cashew kernels may offer protection against cancers of the lungs, liver, skin, brain, and gastrointestinal tract. Cashew kernels contain considerable amounts of vitamin E, an antioxidant that occurs naturally, as well as a small quantity of water-soluble B vitamins such thiamine, riboflavin, niacin, biotin, folic acid, vitamin B6, B12, and pantothenic acid (Bhat, 2008).

Proximate and chemical composition of cashew kernel

Proximate composition, mineral composition, fatty acid composition and vitamin content were described by several authors as shown in Table 2-5 respectively.

According to Usman et al. (2016) and Ojewola et al. (2004), variations in processing proximate composition may result from different processing techniques, environmental factors, storage durations, and crop types. There may be some undefatted rejects in the cashew kernel waste that may have raised the level of the ether extract (Usman et al., 2016). The value of protein ranging from 15.25 – 38.12% across different studies shows that cashew kernel waste can be comparable to other protein-rich food like cowpeas, peanuts, melon, pumpkin, melon, and soybeans. The high amount of crude fiber observed by Swain et al. (2014) could be attributed to a large proportion of shells (Lebas et al., 2012).

A study by Ogunwolu et al. (2010) shows that the moisture content was 0.85, crude protein was 20.56, fat was 4.80, ash was 3.00, nitrogen-free extract was 75.20, the fat was reduced in comparison to the findings of Ojediran et al. (2022c). This is because solvent extraction allows for near-complete oil extraction (Tranchino et al., 1983), and extraction was done to determine whether cashew nuts were suitable for producing protein isolate and concentrate.

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The different techniques employed, the variations in soil composition in each region, and the varying climatic conditions in each study area could all contribute to the variations in chemical and proximate composition of cashew that were identified (Giorgi et al., 2010; Cheng et al., 2014; Ahmed et al., 2014). Cashew kernels provide a high nutritional value that is rich in beneficial sterols, fiber, vitamins, and minerals (Wight et al., 2012; Gupta and Prakash, 2014; Ras et al., 2014; Agnew-Blais et al., 2015; Rico et al., 2015). They also include an abundance of healthy fats. When compared to other nuts like almonds, chestnut, walnut, and hazelnut, cashew kernels contain higher levels of iron (Fe) and zinc (Zn), according to a research by Gonçalves et al. (2023). It was also reported by Gonçalves et al. (2023) that cashew among other nuts are abundant sources of B vitamins.

Table 2. Proximate composition of cashew kernel waste
Tablo 2. Kaju çekirdeği atıklarının proksimat bileşimi

Proximate Fraction (%)	A	B	C	D	E	F	G
Moisture	8.57	0.85	8.90	-	5.00	9.52	9.05
Crude Protein	38.12	20.56	22.10	5.00	18.53	15.25	27.59
Fat	16.10	4.80	40.23	11.70	46.95	46.88	31.84
Ash	5.21	3.00	3.73	1.39	2.44	4.58	3.35
Crude fiber	0.72	-	0.90	27.3	3.45	3.43	3.24
Nitrogen free extract	-	75.20	24.04	-	23.63	20.34	24.92

A- Ojewola *et al*. (2004), B – Ogunwolu *et al*. (2010), C- Aremu and Akinwunmi (2014), Swain *et al*. (2014), E- Usman *et al*. 2016, F– Ojediran *et al*., (2022c), G- Ojediran *et al*. (2022d).

Table 3. Mineral Composition of cashew kernel
Tablo 3. Kaju çekirdeğinin Mineral Bileşimi

Minerals (%)	A	B	C
Calcium	0.4	0.037	0.037
Phosphorus	0.88	-	-
Potassium	0.57	0.66	0.66
Sodium	0.005	0.012	0.012
Magnesium	0.28	0.292	0.292
Manganese	0.002	-	-
Zinc	0.004	-	0.00096-0.0058
Copper	0.002	-	0.00056
Iron	0.008	-	0.0038-0.0067

A – Nandi (1998), B – Segura *et al*. (2006), C- Gonçalves et al. (2023).

Table 4. Fatty Acids Composition of Cashew Kernel Meal
Tablo 4. Kaju Çekirdeği Küspesinin Yağ Asitleri Kompozisyonu

Fatty Acids (%)	A	B	C	D
Palmitic acid	0.89	6.93	8.93	3.92
Stearic acid	11.24	8.42	9.49	3.22
Oleic acid	73.3	67.62	59.59	23.52
Linoleic acid	7.67	16.99	20.20	7.78

A – Nandi, (1998), B- Soares *et al*. (2013), C- Uslu and Özcan, (2019), D- Gonçalves et al. (2023).

Table 5. Vitamin Content of Cashew Kernel Meal
Tablo 5. Kaju Çekirdeği Ununun Vitamin İçeriği

Vitamin Content (mg/100g)	A	B	C
Thiamine	0.56	0.042	0.42
Niacin	3.68	0.34	1.06-1.10
Riboflavin	0.58	0.12	0.06-0.10
Tocopherol	210	1.92	0.0-0.9

A – Nandi, (1998), B – Griffin and Dean (2017), C- Gonçalves et al. (2023)

Nutritive value of cashew byproducts on poultry birds

According to Swain et al. (2007), feeding cashew apple waste in place of maize at all levels had no impact on the characteristics of the carcass or the weights of the organs. Economic analysis showed that substituting cashew apple waste for 20% of the maize lowered the cost of the diet by Rs. 0.6/kg. The group of birds fed a control diet, however, had the highest net profit. The results of the current investigation support the hypothesis that broiler chickens' low growth performance and reduced profit margin were caused by the inclusion of cashew apple waste in their feed.

Song and Seng (2008) found no adverse effect in an eight-week trial providing a one-week-old Khaki Campell ducks diet containing up to 15% dehydrated cashew apples.

According to Bhamare et al. (2016), cashew apple waste is an excellent source of protein and energy and can be added to chicken diets at a rate of 5%. At greater participation levels (10–20%), it significantly slowed growth. The inclusion of cashew pulp meal by Oyewole et al. (2017) in the diet of starter broilers negatively affected the performance of the broilers in terms of the feed conversion ratio and weight gain. It however led to a gradual decrease in cost of feed and there was reduced feed cost at 20% and it was discovered that at 20%, the health of the birds was not affected.

Yisa and Longe (2020) substituted 10% of maize in broiler chicken with dried cashew pulp and discovered no loss of performance as measured by the growth rate, feed conversion, and carcass weight. A substitution rate of 20% was recommended in terms of the advantages for climate change and biodiversity of replacing imports of ingredients.

According to a study by Agbede et al. (2006), defatted cashew nut meal (DCNM) could be added to the diets of broiler chicks up to 22.52% without negatively affecting performance indices. The chicks fed diets based on DCNM also had higher feed conversion ratios than those fed the control diet, indicating that the experimental birds used their diets more efficiently than the control. It is conceivable that the oxidative deterioration of diets and chicken meat from DCNM-based diets could influence both the storability of such diets and the meat produced from them. As consequently, such meat may not be recommended for eating by people at risk for hypertension because a high dietary fat intake has been linked to cardiovascular problems (Onibi, 2006). Additionally, the increased degree of DCNM incorporation decreased the cost/kg weight gain of the birds. According to the study, substituting DCNM for SBM in broiler chick diets would result in a 7–28% cost decrease for farmers. Therefore, it is suggested that DCNM be added to broiler diets up to 28.15 % in areas where cashew nuts are abundant since this will help to lower the price of finished feed and boost the farmers' profit margin.

Another study by Yusuf and Aliyu-Paiko (2020) revealed that the broiler chickens' growth performance and feed consumption were not affected by the inclusion of up to 4% cashew nut meal in starter feed. According to Ojewola et al. (2004), the price of feed per bird and per kilogram decreased when soybean meal protein was used as a substitute for cashew nut meal protein in broiler feed. According to Freitas et al. (2006), adding up to 25% of cashew nut meal to broiler feeds is economically feasible for different phases of rearing without compromising performance or carcass qualities. Another study by Ojediran et al. (2022c) found that undefatted cashew rejects kernel meal can replace up to 50% of full-fat soybean meal in the diet of broiler chicks in terms of feed conversion ratio and serum metabolites.

According to a study by Ojediran et al. (2022c,d), feeding laying Isa Brown hens a diet high in defatted cashew nut meal and full-fat cashew nut meal increased weight gain and feed conversion ratio while also lowering the cost of feed per kilogram of weight gain significantly. According to Karikari et al. (2023), CNM can be included in pullet diets up to 7.5% and laying hen and cockerel diets up to 12.5% without having any negative effects on performance, reproductive, and semen quality parameters.

By using both dry cashew nut meal and full-fat cashew nut meal, Akande et al. (2015) found that the growth performance and egg quality of laying birds were not in any way compromised. Additionally, the cost per unit of cashew nut was much lower than that of groundnut. Cashew nut meal has a significant potential to fill the need for extra protein sources, helping the country save millions of dollars in hard-earned foreign currency per year on importing groundnuts from all over the world. It was shown that DCNM meal enhanced the growth performance of laying hens at a low cost and could be used in the diet of laying birds to completely replace 22% groundnut cake, however, FCNM should be used with caution in laying birds due to its greater at level content.

N*utritive value of cashew byproduct on other monogastric animals*

Oddoye et al. (2009) fed growing pigs in Ghana varying amounts of cashew nut meal in their diets and found that up to 20% did not adversely affect the pigs' performance. A study by Ojediran et al. (2021) discovered that weaned pigs could consume up to 15% of cashew reject kernel meal inclusion level in terms of growth and economic benefits and blood performance.

According to a study by Akpotu et al. (2020), giving Wistar rats a diet containing cashew kernel oil had an adverse effect on the animals' health.

Nutritive value of cashew byproduct on ruminant animals

The ability of dairy calves to produce milk remained unaffected when cashew apples were used in India as a 50% replacement for GNC (Sundaram, 1986). In Vietnam, 90% of the cashew apple waste that was ensiled was acceptable for use as cow fodder, and cashew apple waste can be ensiled alone to achieve the same results, according to Kinh et al. (1997).

According to Okpanachi et al. (2016b), feeding dry cashew pulp meal to West African dwarf goats in Nigeria at a rate of up to 30% did not have an adverse effect on performance metrics. When the inclusion level of sun-dried cashew pulp increased from 0-30% feed cost per kg, total feed cost, and total variable cost of production significantly decreased.

The addition of 24% cashew nut meal to the concentrate portion of dairy cows' diets by Pimentel et al. (2017) maintained milk production, decreased milk fat content, and increased milk's nutraceutical value by decreasing the concentration of short-chain fatty acids and increasing the concentration of long-chain fatty acids. This makes using cashew nuts an excellent substitute for producing milk with more health benefits for humans. Medeiros (2005) and Oliveira et al. (2014) reported that cashew nut meal had no negative effect on sperm quality when it was included at 13-18% of dry matter in a concentrate feed to supplement hay in breeding rams.

According to Branco et al. (2014), CNSL raised the proportion of Succinivibrio while decreasing or tending to decrease the amounts of Butyrivibrio, Barnesiella, and Odoribacter. Dairy cows' rumen methane emission was not affected by CNSL, which has cardanol and cardol as its major active constituents but no anacardic acids. However, when expressed as a percentage of dry matter intake, it tended to fall by 8%. The product did not influence the digestibility of the other dietary components but tended to boost total tract NDF digestibility. The amount of nitrogen excreted in the urine and feces, the type of bacteria present in feces, and the antioxidative state of milk and plasma were not affected by CNSL.

Nutritive value of cashew byproduct on rabbits

Fanimo et al. (2003) fed dry cashew apples to rabbits in place of groundnut and maize up to 30% of the time and concluded that cashew apples were cheaper but had lower digestibility.

Usman et al. (2016) discovered that rabbits fed diets containing up to 75% cashew nut waste as a substitute for maize performed better than those fed diets containing other dietary treatments when evaluated in terms of growth performance, economic profitability, and nutrient digestibility. As a result, it is determined that rabbits can tolerate up to a 75% inclusion level of cashew nut meal (CNM) as a substitute for maize without any negative effects on their performance or digestibility. Utilizing CNM led to lower costs and cheaper diets.

Gomes et al. (2020) discovered that 20% CNM improved production output and economic viability without reducing the nutritional effectiveness of the diet.

Conclusion

Cashew byproducts are valuable sources of nutrients that can be effectively used in livestock feeds. Cashew apple, cashew kernel waste meal, and cashew nut shell liquid residue are desirable options for enhancing animal nutrition because of their high energy and protein contents as well as their inclusion of vital minerals. Cashew utilization has been proven to improve the growth performance, digestibility of nutrients, and general health of animals.

Overall, incorporating cashews into animal feeds has enormous potential to enhance animal nutrition as well as promote the sustainable production of livestock. Livestock farmers can boost the general nutrition, productivity, and sustainability of their animal production systems by utilizing the nutritional profile and beneficial effects of cashew byproducts. Therefore, as a promising method of boosting animal nutrition and welfare, the addition of cashew byproducts to livestock feeds could be promoted.

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