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PROXIMATE ANALYSIS OF PALM KERNEL CAKE MIXED WITH BREWERY WASTE FOR LIVESTOCK FEEDS PRODUCTION FOR SMALL AND MEDIUM SCALE FARMERS

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ABSTRACT

Palm kernels, derived from the extraction of palm fruits, serve as the primary source for producing Palm Kernel Cake, a highly valuable component in livestock feed. This study seeks to comprehensively evaluate the nutritional suitability of Palm Kernel Cake through a comprehensive characterization test. The evaluation centers around essential parameters, including Moisture Content, Ash Content, Crude Protein, Fiber, Fat, and Nitrogen. Additionally, mineral analysis was performed employing the precision of an Atomic Absorption Spectrophotometer. Furthermore, a series of experimental blends with Brewery wastes were examined, with particular attention to identifying the most promising formulations. Among the diverse blends studied, the standout performer emerged as a combination comprising 50% milled Palm Kernel Cake and 25% Brewery waste. This specific blend demonstrated an exceptional equilibrium of critical minerals and chemical constituents necessary for promoting robust livestock growth. The promising outcomes of this blend hold the potential to significantly enhance livestock productivity, strengthen value chains within the agriculture sector, and contribute to overall economic growth. As a result, we strongly advocate the integration of this optimally balanced blend into livestock feed production processes. By harnessing the rich nutrient profile of this blend, agricultural stakeholders can foster economic development, capitalize on abundant nutrient resources, and ultimately drive progress within the livestock industry and beyond.

Keywords: livestock; PKC; amino acid; poultry; waste; ruminants.

INTRODUCTION

The poultry and livestock sectors are important to the world economics which have tremendously improved for the past three decades. Relatively, the poultry industry has significant advantages as they are simpler to manage, quicker returns on investment than any other livestock production, greater productivity [1]. The consumption of poultry products all over the world is high and tends to continue to increase when compared to other livestock products [2]. Meat from poultry is a good source of protein for the well-being of the human body. Besides being readily available and less expensive, its composition makes it an important part of balance and healthy diets [3]. The poultry industry is a vital part of Nigeria economy. Hence, Nigeria as a country has been one of the major consumers of poultry meat, with yearly not less than 45 kg per person [1].

Local poultry farmers have been continuously faced with the high cost of feed; this has drastically increased the high cost of poultry farming. Particularly, this has made high-quality raw materials like corn, soybean, etc., a bit difficult for farmers to access. This has resulted in research efforts into finding a less expensive and locally available material as substitute for energy and protein sources in place of corn and soybean meal [4]. Consequently, large volume of wastes with several disposal challenges to the environment being produced is now looked into as potential source of protein for animals. The residues from agricultural activities are abundance in large quantities and also characterized by affordability, thus making them economically possible to exploit [5].

In both industrial and domestic sectors, agro-wastes like feathers, grass cuttings, poultry litter, droppings, kernel shell from farmyards are commonly produced in large amount [6]. [7] reported about 80% of solid wastes per annum. [8]; [9] reported 327,000 tonnes of agro-wastes being produced in Kuwait while in 2019 Abu Dhabi Emirates generated about 1.3 million tonnes of agro-wastes. Furthermore, it was they also stated in their report that India (605 millio tonnes) and Nigeria (201 million tonnes) of wastes generation annually with most opening burnt as disposal attempt which could result to environmental pollution.

These wastes ranges from shells, fruit peels, hulls, bagasse, barks, leaves, stalks, roots, brans, straws, cobs, husks, pulp, and sludges with shells from extraction of palm kernel generating the highest agricultural wastes [10]. Owing to the high demand of palm oil, high quantities of palm kernel shell (PKS) are produced as wastes which need to utilization for several applications probably because of their low carbon content. Currently, several attempts has been made in the application of PSK for road construction, abrasive in automobile components, wastewater detoxifier, reinforcement for polymeric and metallic composites, livestock feed as well as additives in drilling fluids while at the moment its application in palm kernel cake (PKC) for livestock feeding is scarce.

Feed is an essential production inputs that influence the growth of livestock. And PKC is one un-convention feed gotten from palm oil production that could be utilized as livestock feed which contains 5.0-12.0% oil [11]. Depending on method of oil extraction, source of sample, and type of fruits palm, the chemical constituent of PKC varies (crude fibre, nitrogen free extract, ash, ether extract, and crude protein). The crude protein content in PKC is low when compared with groundnut cake and soybean meal. Many authors have indicated the range of crude protein of palm kernel cake to be between 14.5-20.7% [12]. Several researchers such as [13] reported an average chemical composition of dry matter which is the proportion of water content in the cake as 88.0-95.0%, [14] reported crude fibre of 5.9-23.5%, [15] reported acid detergent fibre of 44.7%, lignin content of 22.3%, and neutral detergent fibre of 65.7%. Furthermore, [11] reported ether extract of 0.6-3%, expeller pressed of 4.6-18% while 3.08 and 6.5% for total ash content. Several studies have reported the satisfactory performance of animals when fed with palm kernel cake diets. The protein content of PKC is low in lysine, amino acid balance followed by tryptophan, methionine, histidine, and threonine contents [16]. The crude fibre which consists majorly of hemicellulose, cellulose, and lignin contents is an index used to predict the nutrient digestibility (which makes it applicable for only ruminants) and feeding value of the animals. The sugar content in PKC fibre is majorly contributed by mannose (55.8%), glucose (12.1%), xylose (3.9%), and galactose (1.3%)[17]. However, PKC is relatively high in phosphore (0.656 %), calcium (0.268%), magnesium (0.186%), sodium (0.196%), zinc (0.232%), copper (0.26%), potassium (0.336%), iron (0.76 ppm), and manganese (1.4 ppm) mineral contents [13].

For animals (ruminants) for example pigs to perform optimally with respect to body weight, growth, health, and reproduction they must be fed appropriately with the required nutrients. This has led several research efforts into blending PKC with different valuable additives. However, this study seeks to blend palm kernel cake with brewery wastes as this consists of vital mineral ingredients such as high total nitrogen, phosphorus, organic matter, sugar, ethanol, soluble starch, fatty acids, proteins, low pH levels, etc.

Both physical and chemical treatments were used in different studies to improve different species of palm kernel cake nutrient. In processing the chemical properties, the used of alkaline or acid solutions has been suggested to influence the nutritive values and nutrients digestibility by decreasing crude fibre and increasing crude protein contents [18]. Even though it has been reported that palm kernel cake contained lots of protein, minerals, vitamins, and energy there still existed lack of information at our disposal regarding its physicochemical properties of palm kernel cake.

Therefore, the aim of this study is to carry out characterization on different blends of brewery waste with PKC species so as to screen to a more suitable feed for livestock. We believe that the information obtained could guide poultry farmers and scientists to make informed decisions on the best feeds for livestock from locally made source with the added advantage of saving the environment from carbon emission through indiscriminate burning of palm kernel wastes.

METHODS

Moisture content

The moisture content was done by weighing 2g of the crushed sample into a crucible and was placed in a drying oven at 105°C for 12 hours and was allowed to cool in a desicator. The sample was weighed again. The difference in the mass constitutes the amount of moisture adsorbed [19].

Calculation

Moisture content (%) = ((B-A)-(C-A))/((B-A))

A =weight of crucible (g)

B = weight of crucible + sample before drying (g)

C = weight of crucible + sample after drying (g)

Ash content

2g of the dry crushed sample was placed in a crucible and placed in a furnace and heated at 550°C for 12 hours and was allowed to cool before it was transferred to a dessicator. The resulting mass was weighed again

Calculation

Ash content = (A-B)/C 100

A= weight of crucible (g)

B = weight of crucible with ash (g)

C = weight of sample (g)

Crude protein, crude fibre, crude fat and nitrogen free extract

For the determination of crude protein, crude fibre, crude fat and nitrogen free extracted were determined according American Standard for Testing and Material (ASTM) as provided by the [20].

Mineral / chemical analysis

The mineral and chemical analyses of representative samples were conducted using an Atomic Absorption Spectrophotometer (AAS, Perkin Elmer 2380). The samples were first dried until a constant weight was achieved. Subsequently, they were digested for thirty minutes in 100mL of hydrochloric acid, maintained at a low heat of 50°C within an oven. The solid components within the solution were extracted using 2M hydrochloric acid and nearly evaporated to dryness. This residue was then re-dissolved in 10mL of concentrated hydrochloric acid with the addition of ten drops of 1M trioxonitrate (V).

The resulting solution was transferred into a 50mL volumetric flask and diluted with distilled water. It was then filtered through blue ribbon filter paper (S&S 11589) into another volumetric flask, which was subsequently analyzed for metal concentration using the Atomic Absorption spectrophotometer (Perkin Elmer 2380). A digestion blank was also carried out following the same procedure [21].

For analysis, the digested and extracted samples were aspirated into the flame as a fine mist through an air stream. The sample entered the burner through a mixing chamber where the air met the fuel gas (acetylene). This mixture was combusted, and the resulting flame's radiation passed through a lens to the monochromator, then through an optical filter that allowed only the radiation characteristics of the metal being analyzed. Finally, the radiation passed through a photocell, and the result was read on a monitor. Optical densities of standard solutions containing various metal ions were measured at their respective wavelengths, and standard curves were prepared by plotting absorbance against metal concentrations [22].

RESULTS

Table 1 Results of Proximate Analysis of Palm Kernel Cakes and Brewery waste

Sample type	Moisture (%)	Crude protein (%)	Crude fibre (%)	Crude fat (%)	Nitrogen free extract (%)	Ash (%)
Tenera (100%)	8.16	13.20	8.10	8.11	50.18	5.66
Dura (100%)	7.21	12.31	7.80	8.07	47.81	4.71
Brewery waste (BW) (100%)	6.61	26.11	18.61	5.11	45.61	2.01
Tenera (50%) BW (50%)	9.86	28.14	20.77	10.86	58.40	6.11
Dura (50%) BW (50%)	9.46	24.66	19.34	10.16	53.66	4.71
Tenera (75%) BW (25%)	9.04	18.60	19.10	9.10	50.60	4.14
Dura (75%) BW (25%)	8.10	20.60	20.11	9.40	52.46	5.81
Okomu (100%)	9.11	16.86	15.12	9.35	54.60	4.66

Table 2: Results of mineral composition of Palm Kernel Cakes and Brewery waste

Sample type	Calcium	Phosphorous	Magnesium	Copper	Iron	Manganese	Potassium
Tenera (100%)	0.26	0.57	0.24	26.14	884	138	0.81
Dura (100%)	0.21	0.61	0.20	24.11	671	84	0.90
Brewery waste (BW) (100%)	0.11	0.27	0.16	2.17	128	76	0.16
Tenera (50%) BW (50%)	0.37	0.86	0.34	28.41	901	143	1.20
Dura (50%) BW (50%)	0.33	0.91	0.29	26.60	808	94	1.41
Tenera (75%) BW (25%)	0.31	0.58	0.28	27.18	890	140	1.31
Dura (75%) BW (25%)	0.30	0.84	0.31	27.10	803	91	1.10
Okomu (100%)	0.25	0.46	0.18	25.52	715	116	0.18

DISCUSSION

Table 1and 2 above showed the results of proximate analysis and chemical and mineral composition of palm kernel cakes and brewery waste.

Moisture content

Moisture content plays a pivotal role in shaping the sensory experience of food for consumers. Alterations in moisture levels can significantly impact flavor, texture, and both physical and chemical attributes. This is because water serves as a facilitating medium for catalyzing chemical reactions, known as water activity. The amount of free moisture directly correlates with water activity; when water activity is higher, food becomes more susceptible to interactions with microorganisms and its surrounding environment [22].

The results of moisture content was found in the range of 6.61 – 9.86% with tenera, dura and brewery waste recording 8.16, 7.21 and 6.61%. 50% tenera and dura with 50% of brewery waste recorded 9.86 and 9.46% while 75% tenera and dura with 25% brewery waste recorded 9.04 and 8.10% respectively.

The moisture content of tenera was higher than dura while waste was the least. The combination the palm kernels with brewery waste showed tenera to be higher than dura at different percentage.

Figure 1 shows the various moisture content of the analyzed palm kernel cakes, brewery waste and different mixtures of palm kernel and brewery waste.

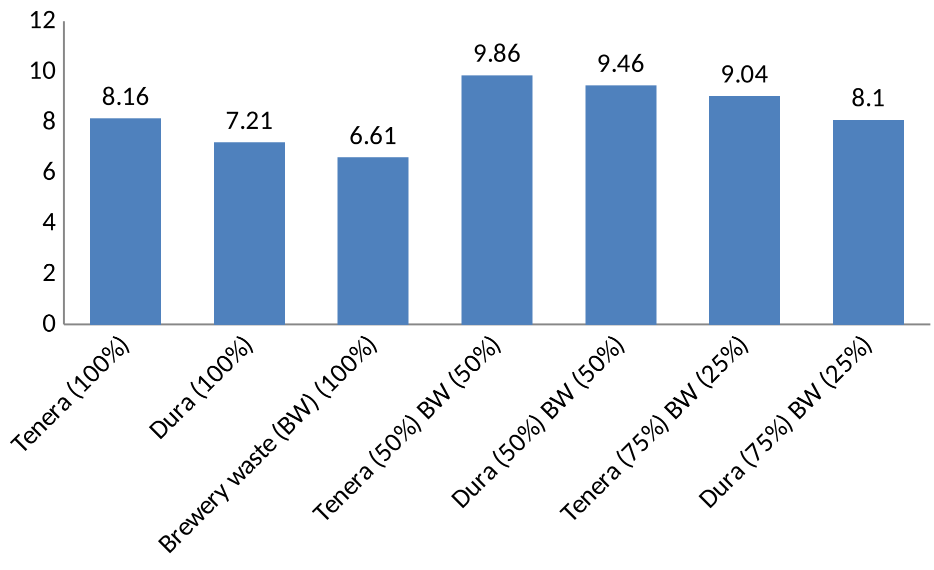

Figure 1: Moisture content of palm kernel cakes and brewery waste

Ensuring consistent and appropriate moisture levels in animal feed is imperative for achieving top-notch final products. Inadequate moisture control poses risks such as mold formation and other hazards. In contrast, maintaining stable and optimal moisture levels assures uniformity in animal food products and minimizes waste. When animal feed is either excessively wet or dry, it not only leads to financial and time losses for manufacturers but also adversely impacts the overall product quality [23].

Ash Content:

Ash content analysis involves the incineration of organic matter in food, leaving behind inorganic minerals. This analysis helps determine the quantity and composition of minerals in food, a crucial factor as mineral levels can influence the physiochemical properties of foods and inhibit microbial growth [24].

The ash content of this study range from 4.71–7.11% with tenera, dura and brewery waste recording 5.66, 4.71 and 2.01% respectively; mixture of 50% tenera, dura and 50% brewery waste recorded 6.11 and 4.71% respectively while mixture of 75% of tenera, dura and 25% brewery waste recorded 4.14 and 5.81% respectively.

Figure 2 shows the ash contents of the various palm kernels, brewery waste and mixtures

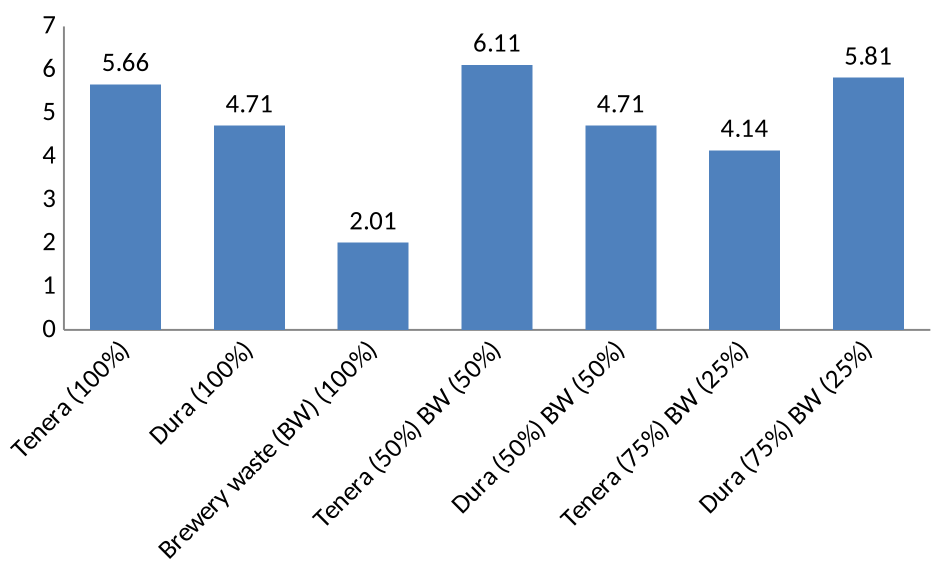

Figure 2: Moisture content of palm kernel cakes and brewery waste

Crude fibre

Crude fibre was found present in the palm kernel cakes and brewery waste in the range of 7.80–20.11%. The palm kernel cakes recorded low crude fibres but the values were triggered when mixed with the brewery waste.

Figure 3 shows the percentage value of crude fibre in the palm kernel cakes, brewery waste and palm kernel cakes mixed with brewery waste at different percentages.

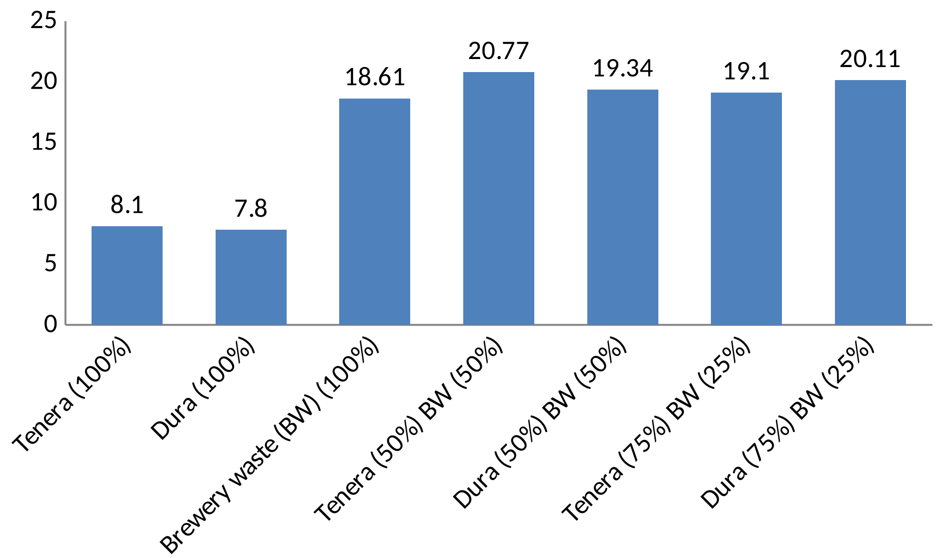

Figure 3: Crude fibre content of palm kernel cakes and brewery waste

Crude fiber content represents the constituents of plant cell walls, encompassing cellulose, hemicellulose, and lignin, which are typically minimally digestible or not digestible at all. Consequently, this portion of the feed lacks energy value for animals. Nevertheless, analyzing crude fiber remains pertinent for feed producers. They not only have a regulatory obligation to disclose the crude fiber content in their products but also recognize that a certain level of crude fiber in the feed is advantageous for animal well-being. Crude fiber promotes digestion and fosters the proliferation of essential gut bacteria. Therefore, the inclusion of crude fiber in animal feed largely hinges on the intended purpose of the feed [25].

Crude protein

Crude protein was found present in the kernel cakes and brewery waste in the range of 12.31–28.14%. As was observed in the crude fibre content of the various kernels, the crude proteins were also lower compared to the brewery waste and the various mixtures formed. 50% mixture of the palm kernels and brewery waste were higher than that of the 75% kernels mixed with 25%. This showed that the composition of 75:25 is the best combination for animal feed as the case may be.

Figure 4 shows the different content of crude protein in the palm kernels, brewery waste and mixture of palm kernel and brewery waste.

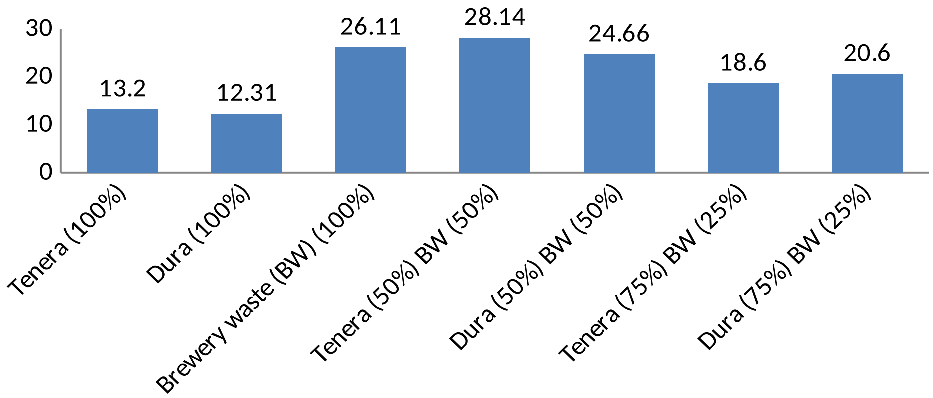

Figure 4: Crude protein content of palm kernel cakes and brewery waste

Maintaining appropriate levels of crude protein is paramount in forage for the diverse array of livestock dependent on it for nourishment. In cases where the crude protein content is insufficient, the crucial digestive bacteria are unable to maintain the requisite levels for processing the forage effectively. Consequently, this deficiency leads to diminished intake and digestibility by the animals. It's worth emphasizing that while crude protein (CP) serves as a vital and frequently employed metric for assessing feed quality, it should not be employed as an indicator of energy value [26].

Crude fat

The concentration of crude fat in palm kernels and brewery waste range from 5.11–10.86%. The lowest crude fat was recorded by the brewery waste (5.11%) while the highest was 50% mixture of tenera palm kernel and 50% brewery waste as can been seen from the figure below.

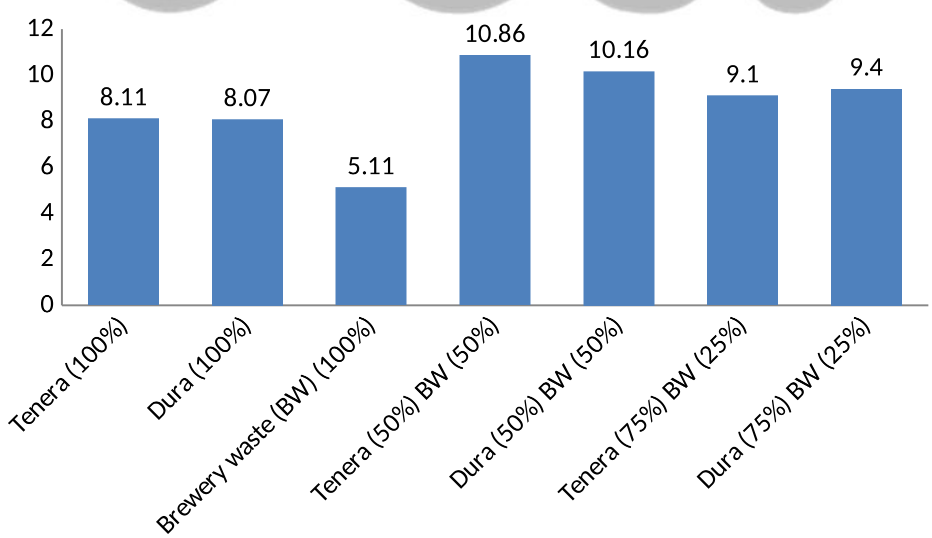

Figure 5: Crude fat content of palm kernel cakes and brewery waste

Incorporating crude fats into animal feeds serves as a highly concentrated energy source, elevating the energy density of the feed mixture. The addition of fats and oils not only boosts energy levels but also reduces dustiness in the feeds and diminishes the presence of fine particles in pellet diets. These enhancements contribute desirable qualities that hold intrinsic value [27].

Nitrogen-Free Extract:

The concentration of nitrogen-free extract within the palm kernels and brewery waste ranged from 8.5% to 45.61%. The lowest value was observed in brewery waste, while the highest was found in a blend consisting of 50% tenera and 50% brewery waste. It's worth noting that in the customary analysis of animal rations, nitrogen-free extract constitutes the largest portion, accounting for 40-70% of the total dry matter. This component serves as a vital source of energy for bodily processes and facilitates the deposition of fat within animal feeds [27].

The figure below therefore shows the various concentrations of free nitrogen extracts of the various components analyzed.

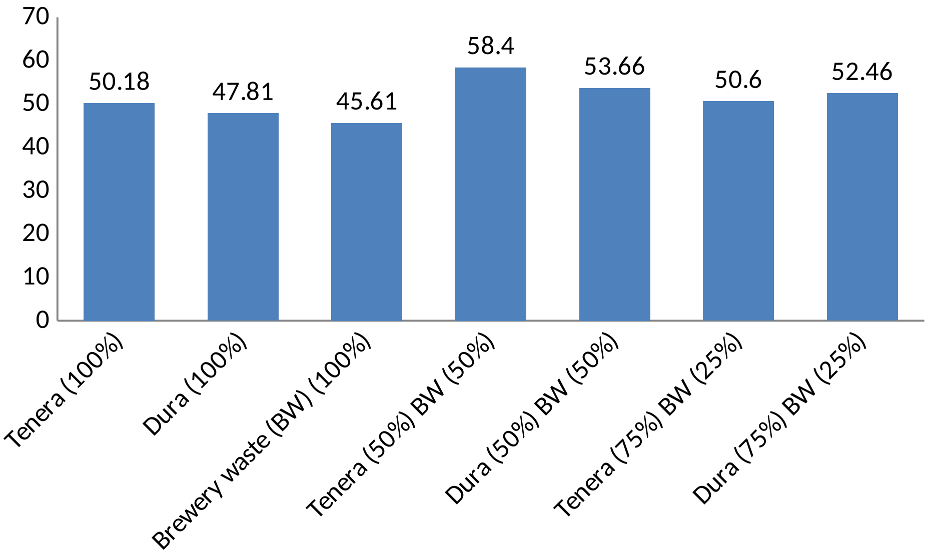

Figure 6: Nitrogen free extract content of palm kernel cakes and brewery waste

Calcium

Calcium assumes a pivotal role in nutrient absorption through the modification of cell permeability and plays a critical part in the blood clotting process. It holds special importance in poultry laying flocks, contributing significantly to the formation of robust eggshells. For cattle, calcium fosters robust growth by promoting optimal bone development [28].

Calcium Concentration:

The concentration of calcium was measured within the range of 0.11–0.37 mg/kg. Palm kernels exhibited higher levels of calcium compared to brewery waste, but the inclusion of brewery waste in various mixtures enhanced the overall calcium content. Notably, the blend of 50% palm kernels and 50% brewery waste demonstrated an improved calcium concentration. This highlights that combining palm kernels with brewery waste can be beneficial for promoting healthy bone development in livestock [28].

Phosphorous

The phosphorus concentration fell within the range of 0.27–0.91 mg/kg, with palm kernels exhibiting higher levels compared to brewery waste. The inclusion of brewery waste in palm kernels tended to elevate the phosphorus concentration, mirroring the trend observed in calcium concentration, particularly with the 50%:50% blend of dura and brewery waste recording the highest levels.

Importance of Calcium (Ca) and Phosphorus (P):

Calcium and phosphorus are among the most abundant minerals in the body, underscoring their crucial role in feed testing and ration balancing for animals. Understanding the significance of these minerals and their functions in the body is essential for ranchers to ensure a balanced mineral program and achieve success [29].

Functions of Calcium and Phosphorus:

Due to their abundance in the body, comprehending the functions and meeting requirements for calcium and phosphorus is vital to prevent deficiencies and toxicities. Both minerals primarily function in skeletal support, with approximately 99% of calcium residing in the skeleton, and about 80% of phosphorus found in bones and teeth. The remaining calcium serves roles in nerve conduction, muscle contraction, blood clotting, and immune system activation, while phosphorus is involved in energy utilization, transfer, acid-base and osmotic balance, and is essential for the growth and cellular metabolism of ruminal microbes in animals [30].

While it's essential to be vigilant regarding the potential toxicity of Ca or P in animal diets, deficiencies can also arise at various points in the production cycle, contingent on the feed source. Generally, forages offer adequate Ca levels, particularly when legumes are included. Ca deficiency is more likely to occur shortly after calving when the animal's Ca loss during lactation surpasses Ca intake. Seasonal factors can exacerbate this, with low Ca levels in forage potentially leading to the withdrawal of Ca from bone reserves, often referred to as milk fever [31].

In growing animal diets, the importance of feed testing and mineral balance becomes even more critical. These animals have higher Ca requirements, and concentrated feeds commonly used in back grounding or finishing contain lower Ca levels compared to forages.

Conversely, phosphorus deficiency is the most prevalent mineral deficiency worldwide. Forages, which constitute the primary feed for ruminants, are generally poor sources of phosphorus. A deficiency in phosphorus can result in a range of problems, including reduced growth and feed efficiency, decreased appetite, impaired reproductive efficiency, diminished milk production, and the development of weak or brittle bones, known as rickets [31].

Magnesium (Mg) Concentration:

Magnesium (Mg) concentration in the palm kernels and brewery waste range from 0.16 – 0.34mg/kg with the brewery waste recording the lowest concentration while the highest was the combination of mixture of 50%:50% tenera and brewery waste. The presence of the brewery waste was also observed to have improved the concentration of magnesium in the palm kernel cakes.

Magnesium (Mg) supplementation remarkably improves the digestibility of feed. In cows and sows, it has improved the reproduction and shortened the service period. In broilers it increased weight gain, and it has increased egg production of laying hens. In addition, increasing Mg intake benefits the quality of breeding eggs and improves hatching yield. However, increasing Mg intake has not altered visceral composition of embryos, although brain and liver might have the capacity to store Mg at intake above the requirement [32].

The combination of 50%:50% tenera and brewery waste was observed to be the best combination followed by 75%:25% dura and brewery waste.

Copper (Cu) Concentration:

Copper concentration was notably higher in palm kernels compared to brewery waste. Specifically, tenera and dura palm kernels recorded concentrations of 26.14 and 24.11 mg/kg, while brewery waste exhibited a lower concentration of 2.17 mg/kg. The presence of brewery waste did, however, lead to an improvement in copper content when combined with palm kernels, particularly in the 50%:50% blend of tenera and brewery waste, the 75%:25% blend of tenera and brewery waste, and the 75%:25% blend of dura and brewery waste.

Importance of Copper (Cu):

Copper is a vital trace element essential for animals, contributing to body, bone, and wool growth, pigmentation, the health of nerve fibers, and the proper function of white blood cells in both animals and humans. While including copper in animal diets is a common practice, several factors must be considered. Copper's significance became evident in the 1930s when it was found to be an essential nutrient for maintaining hemoglobin levels, despite its relatively low presence in blood. Interest in copper grew further when it was shown to address certain cattle diseases attributed to copper deficiency [33].

Iron (Fe) Concentration:

Monogastric animals like pigs and poultry are not concerned with the quantity of iron incorporated into their feeds. They can tolerate substantial excesses of iron, whereas natural ingredients typically contain almost enough iron to sustain them at an acceptable, though not necessarily profitable, condition [34].

The concentration of iron in palm kernels and brewery waste ranged from 128 to 901 mg/kg, with brewery waste having the lowest concentration at 128 mg/kg. The highest concentration was observed in the 50%:50% blend of tenera and brewery waste, with an increase attributed to the presence of brewery waste.

Importance of Iron (Fe) for Piglets:

Inadequate iron intake in piglets results in insufficient hemoglobin production, leading to reduced growth, inadequate weight gain, and ultimately, anemia. Early signs of iron deficiency anemia include paleness and failure to thrive. In severe cases, clinical symptoms emerge, including stunted growth, breathlessness, and chronic diarrhea, stemming from a compromised immune system. If left untreated, anemia can prove fatal. Preventing iron deficiency anemia in piglets is straightforward with an iron injection shortly after birth, and selecting the right iron supplement can have a significant impact [34].

Potassium (K) Concentration:

The concentration of potassium (K) was identified within the range of 0.16–1.41 mg/kg. The 50%:50% blend of dura and brewery waste mixture recorded the highest value at 1.41 mg/kg, while brewery waste exhibited the lowest value at 0.16 mg/kg. Notably, the presence of brewery waste contributed to an increase in the potassium concentration in palm kernel cakes. Consequently, the most favorable combinations are the 50%:50% mixtures of dura and brewery waste and tenera and brewery waste.

Importance of Potassium (K):

Potassium (K) stands as the primary intracellular mineral ion in both humans and animals. Plant-derived feedstuffs play a pivotal role in supplying potassium in most animal diets. Regulating extracellular K levels, including those in the plasma, is vital for maintaining normal bodily health and cellular function. Many nutritionists have observed significant enhancements in appetite and increased milk production in dairy feeds when potassium supplementation was applied, even in cases where feeds were assumed to contain sufficient potassium. This underscores the importance of addressing the variability of potassium in feed sources and considering its bioavailability [32].

Manganese (Mn) Concentration:

Manganese (Mn) is a trace mineral that constitutes a dietary essential for animals. Within the animal body, Mn is distributed throughout but is notably concentrated in bone and the liver. It plays a vital role in the maintenance and production of the mucopolysaccharide, a component of the organic matrix of bone [34].

Manganese concentration in palm kernel cakes and brewery waste fell within the range of 76–143 mg/kg. The highest concentration was observed in the 50%:50% blend of tenera and brewery waste, primarily attributable to the presence of brewery waste. This was followed by the

75%:25% blend of tenera and brewery waste. Consequently, the presence of brewery waste is a valuable factor for the manganese content in animal feed production.

Role of Manganese (Mn) in Bone Health:

Manganese is essential for bone formation and overall bone health. In Mn-deficient animals, tendon growth remains normal, but bone growth is slowed or altered, leading to symptoms like perosis (slipped tendon) in chicks and crooked calf in young ruminants. Additionally, manganese acts as a crucial cofactor for numerous enzymes involved in carbohydrate, fat, and protein metabolism. A significant portion of manganese resides within mitochondria, where it activates various metal-enzyme complexes that regulate carbohydrate metabolism, such as pyruvate carboxylase. Manganese also plays a role in lipid metabolism by contributing to cholesterol and fatty acid synthesis. Dietary manganese absorption is generally poor, accounting for less than 10% of intake, and excessive dietary calcium or phosphorus can hinder manganese absorption. Manganese is absorbed from the gastrointestinal tract as Mn^{2+}, undergoes oxidation to Mn^{3+}, and is transported to tissues with transferrin as a carrier. Overconsumption of manganese in the diet can induce iron deficiency [34].

CONCLUSION

The utilization of palm kernel cake, either independently or in combination with brewery waste, presents a promising resource for livestock production. Palm kernel cakes derived from tenera and dura species exhibited notable attributes, including moisture content, ash, crude fiber, crude protein, crude fat, and nitrogen-free extract. The presence of these essential components in the analyzed palm kernels and their blends with brewery waste underscores their suitability for the production of preferred livestock.

Moreover, the mineral compositions of these palm kernel cakes and their combinations with brewery waste are found to be well-balanced. Brewery waste has the remarkable capability to enhance the presence of vital minerals and chemicals, including calcium, phosphorus, magnesium, copper, iron, manganese, and potassium when blended in ratios of 50:50 and 75:25 with palm kernels and brewery waste, respectively.

In light of these findings, it is recommended that palm kernel cakes from both tenera and dura species, blended with 50% and 25% brewery waste, respectively, be considered for livestock production. All evidence suggests that they contain the essential minerals and chemicals required for the health and well-being of livestock. These resources, along with other arable forage options, hold great potential as valuable sources of nutrition for livestock when used alone or in combination with complementary materials.

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