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Effect of Microbial Treated Rice Husk Diets on Milk Physicochemical Properties of West African Dwarf Does During Lactation

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Abstract

Rice husk is an abundant agro-industrial by-product in tropical regions, but its utilization in ruminant feeding is limited due to high fibre and low digestibility. Microbial treatment has been proposed as an effective strategy to enhance its nutritive value and improve livestock productivity. This study evaluated the effects of microbial-treated rice husk–based diets on milk physicochemical properties of West African Dwarf (WAD) does during lactation. Forty lactating WAD does (12–14 kg body weight) were randomly allotted to four dietary treatments in a completely randomized design: T1 (maize-based control), T2 (bacterial-treated rice husk), T3 (fungal-treated rice husk), and T4 (combined bacterial and fungal-treated rice husk). Milk samples were collected weekly and analyzed for moisture, total solids, density, pH, titratable acidity, fat, protein, lactose, solid-not-fat, ash, salt content, and freezing point using standard analytical procedures. Results showed that moisture content and protein were significantly ($P < 0.05$) influenced by dietary treatments, with the highest protein value recorded in T1. Density also differed significantly among treatments, whereas total solids, fat, lactose, ash, and freezing point were not significantly affected ($P > 0.05$). Across lactation weeks, moisture increased progressively, while total solids, fat, and protein declined, reflecting physiological changes associated with advancing lactation. The findings demonstrate that microbial-treated rice husk diets can be incorporated into WAD goat feeding systems without detrimental effects on milk physicochemical quality. However, lactation stage remained the dominant factor influencing milk composition. These results highlight the potential of microbial processing techniques to improve the utilization of crop residues in sustainable dairy goat production systems in the tropics.

Keywords: *West African Dwarf goats; Microbial treatment; Rice husk; Milk composition; Lactation; Agro-industrial by-products.*

Introduction

Goat production plays a vital role in sustaining rural livelihoods and enhancing food security in tropical and sub-tropical regions, particularly among smallholder farmers who depend on resilient livestock species (Ranadheera et al., 2023; Wang et al., 2023). Among indigenous breeds, the West African Dwarf (WAD) goat is widely recognized for its adaptability to humid environments, tolerance to diseases, and ability to utilize low-quality feed resources efficiently (Claps et al., 2022; Park et al., 2021). These characteristics make WAD goats an important source of meat and milk for households in West Africa, especially in regions where conventional feed resources are limited or expensive. Goat milk is increasingly valued for its high nutritional quality, digestibility, and therapeutic potential, particularly for children, elderly individuals, and people with lactose intolerance or cow milk allergies (Mele et al., 2021; Ranadheera et al., 2023). The physicochemical composition of goat milk, including moisture, fat, protein, lactose, minerals, and acidity, determines its nutritional value, processing characteristics, and consumer acceptability (Park et al., 2021). However, milk composition is influenced by several factors, including breed, feeding regime, environmental conditions, and stage of lactation (Akar et al., 2022; Wang et al., 2023). Among these factors, nutrition and lactation stage are considered the most critical determinants of milk quality parameters. Feed availability remains a major constraint to sustainable goat production in tropical regions, particularly during dry seasons when conventional feed resources are scarce. Consequently, the use of agro-industrial by-products such as rice husk has gained attention as an alternative feed resource (Claps et al., 2022; de Souza et al., 2023). Rice husk is widely available in rice-producing regions but is characterized by high lignocellulosic content, low protein levels, and poor digestibility, which limit its direct use in animal feeding (Li et al., 2022; Zhuang et al., 2024). To improve its feeding value, microbial treatment methods involving bacteria and fungi have been developed to degrade structural carbohydrates and enhance nutrient availability (Balthazar et al., 2021; de Souza et al., 2023).

Recent studies have demonstrated that microbial fermentation of fibrous feed materials can improve digestibility, increase crude protein content, and enhance rumen microbial activity, thereby improving milk yield and composition in ruminants (Claps et al., 2022; Wang et al., 2023). Additionally, dietary manipulation through treated feed ingredients has been reported to influence milk physicochemical properties such as protein content, pH stability, and mineral balance (Akar et al., 2022; Ranadheera et al., 2023). Despite these advancements, limited information is available on the effects of microbial-treated rice husk diets on milk quality characteristics of WAD goats under tropical production conditions. Understanding the interaction between dietary treatments and lactation physiology is essential for optimizing milk quality and improving the productivity of indigenous goats. Moreover, evaluating physicochemical parameters of milk provides valuable insight into the nutritional adequacy of diets and their suitability for dairy processing applications (Park et al., 2021; Mele et al., 2021). Therefore, this study was conducted to evaluate the effects of microbial-treated rice husk diets on the physicochemical properties of milk from West African Dwarf does during lactation. The findings are expected to contribute to improved utilization of agro-industrial residues and support sustainable dairy goat production in tropical environments.

Materials And Methods

Experimental Location

The study was conducted under standard management conditions typical of tropical smallholder systems. The study was conducted across two locations in Kwara State, Nigeria. The microbiological inoculation was performed at the University of Ilorin Microbiology Laboratory (8^{0}28'55"N, 4^{0}40'18"E), while the growth trial was carried out at Afolayan Livestock Farm, Oro, Irepodun Local Government Area (8.13^{0}N, 4.50^{0}E).

Experimental Animals and Diets

Four groups of lactating WAD Does were assigned to four dietary treatments (T1, T2, T3, and T4). Diets were formulated to meet the nutritional requirements of lactating goats. Forty (40) adult WAD does weigh between 12-14 kg were allotted to four treatments. The goats were given a prophylactic treatment. The goats were dewormed with levamizol intramuscular injection at the rate of 1 ml / 20 kg body weight, they were also injected ivomec at the rate of 1 ml / 40 kg body weight subcutaneously against ecto and endo parasite respectively. Antibiotic drug (oxyteracylin) was also administered intramuscularly at the rate of 1ml/10kg body weight. The animals were futher dipped in diazintol solution against ecto parasite and finally vaccinated against peste-de-petil ruminate (PPR) using tissue culture rinderpest vaccine (TCRV) at the rate of 1 ml / animal subcutaneously on the neck region. During this experiment period, the animals were individually penned where experimental diets were offered for fourteen days of the adjustment period prior to the commencement of the experiment. Weighted quantities of the feed were offered once in a day. The concentrate was served in the morning (0800 hours) and the previously cut forages (*Danellia oliveri*) were served in the afternoon (1200 hour) ad-libitum. The animals had free access to water and salt lick throughout the experiment. The difference between the feed served and the leftover gives the feed intake per day. The data obtained were used to determine daily feed intake (DFI).

Experimental Design

The animals were allotted into four treatments of ten animals per treatment based on weight. Individual animals were completely randomized within the experimented pen in the unit.

Diet Formation

Four diets were formulated
T1: Maize-based control
T2: Bacterial-treated rice husk
T3: Fungal-treated rice husk
T4: Bacterial + fungal treated rice husk (Curtail)

Feeding and Monitoring

The goats were fed with their respective weighed diets once daily with water served ad libitum and feed intake was recorded. The feed was measured and served to the animals by 8:00am daily; while leftover was weighed and recorded while in the evening Forage (*Danellia oliveri*) of 1 kg/goat/day was also fed to the animal as their basal diet by 4:00pm. The difference between the feed served and the leftover gives the feed intake per day. The data obtained were used to determine daily feed intake (DFI).

Milk Sampling and Analysis

Milk samples were collected weekly for twelve weeks. The following parameters were analyzed using standard procedures: Moisture content, Total solids, Density, pH, Titratable acidity, Fat content, Protein content, Lactose content, Solid non-fat, Total ash, Salt content, and Freezing point.

Analytical Procedure

Milk samples were pooled together and wormed to 40^0C to melt the butterfat then cooled to 20^0C. Milk samples were analyzed for the following parameters: crude protein, lactose, fat, total solid, solid-not-fat, total ash and milk pH. Solid -not-fat content of milk was calculated as the differences between the total solids and fat composition of milk. Total solid was determined by drying 10ml of milk sample over asbestos powder at 105^0C to constant weight for 24 hours in a regulated oven. Total ash was determined when 5ml of milk sample was evaporated to dryness and ash in a muffle finance at 500 – 550^0C for almost 2 hours.

Lactose was assessed using spectrophotometric method in which 65.8g of well mixed, milk was weighed in to 100 ml volumetric flask and 3 ml of mercury nitrate was added and made up to mark with distilled water. The suspension is filtered, a clear filtrate was obtained, the fats and proteins had been precipitated by the mercury nitrate. A 200 mm polarizing tube is filled with distilled water and placed in the polarimeter. The instrument was adjusted for even illumination of the field and read to determine zero level. The tube was empty, washed out several times. The tube was replaced in the polarimeter and the instrument again adjusted for illumination of the field. The scale is read and differences between the two readings, divided by two, gave the percentage lactose in the milk. Crude protein was determine as outlined by A.O.A.C. Milk fat was assessed as outlined by Werner Schmid method A.O.A.C. pH was measured with pH meter

Statistical Analysis

Data were analyzed using ANOVA, and significant differences among treatment means were separated using appropriate post hoc tests. Significance was declared at $P < 0.05$.

Table 1: Composition of Experimental diets Fed WAD Goats.

	Treatments (Kg)			
Ingredients	TI (control)	T2 (F. Treated)	T3 (B. Treated)	T4 (F+B. Treated)
Treated rice husk	-	25	25	25
Maize	25	-	-	-
Soya beans meal	15	15	15	15
Palm kernel cake	10	10	10	10
Groundnut cake	10	10	10	10
Cassava peel	20	20	20	20
Wheat bran	15	15	15	15
Bone meal	2.5	2.5	2.5	2.5
Salt	1	1	1	1
Premix	1.5	1.5	1.5	1.5

T1(control) = Maize diet, T2 = Bacterial treated rice husk diet, T3 = Fungi treated rice husk diet, T4 = Fungi + Bacterial treated rice husk diet.

Results And Discusions

The summary of milk physicochemical properties of West African Dwarf (WAD) does fed experimental diets is presented in Table below. Moisture content varied significantly ($P < 0.05$) among treatments, with T1 recording the highest value (86.18%) and T2 the lowest (80.19%). A corresponding inverse trend was observed in total solids, although differences were not statistically significant ($P > 0.05$). Milk pH was significantly influenced ($P < 0.05$) by dietary treatments, with T1 showing higher values compared to other treatments. Titratable acidity remained relatively stable across treatments, indicating no major variation in milk acidity. Density values were consistent across treatments, suggesting uniformity in milk composition. Fat and solid-not-fat (SNF) contents showed no significant differences ($P > 0.05$), although T1 tended to record higher values. Freezing point and ash content also remained stable across treatments, indicating no significant changes in mineral composition or osmotic balance. Protein content was highly significantly affected ($P < 0.01$), with T1 recording the highest value (6.18%), while T3 recorded the lowest (4.34%). Lactose content showed slight variation but was not significantly affected by dietary treatments.

Table 2: Summary of Milk Physicochemical Properties of WAD Does Fed Experimental Diets (Day 1–5)

	Treatments					
Parameter	T1 (Mean)	T2 (Mean)	T3 (Mean)	T4 (Mean)	SEM Range	Significance
Moisture (%)	86.18	80.19	84.66	82.93	0.88 – 1.69	*
Total Solids (%)	14.94	13.68	12.88	14.35	0.88 – 2.08	NS
Density (g/L)	1049.36	1038.96	1037.07	1037.41	3.23 – 7.34	NS
Ph	6.59	6.19	6.40	6.33	0.12 – 0.18	*
Titratable Acidity (%)	0.16	0.16	0.15	0.16	0.004 – 0.006	NS
Salt (%)	0.83	0.78	0.75	0.79	0.04 – 0.07	NS
Fat (%)	4.71	4.36	4.05	4.37	0.25 – 0.42	NS
SNF (%)	9.98	9.49	8.81	9.80	0.32 – 1.19	NS
Freezing Point	-0.51	-0.55	-0.56	-0.55	0.01 – 0.11	NS
Ash (%)	0.85	0.83	0.81	0.81	0.02 – 0.04	NS
Protein (%)	6.18	4.63	4.34	4.75	0.22 – 0.43	**
Lactose (%)	4.47	4.19	4.07	4.09	0.13 – 0.17	NS

Significant (P < 0.05), ** = Highly significant (P < 0.01), NS = Not significant. Values are treatment means across experimental days.

The higher moisture content observed in T1 and T3 is consistent with findings in Dairy Science, where increased water fraction in milk is associated with physiological adaptation during lactation and dietary energy balance. Studies by Li et al. (2022), Wang et al. (2023), and Zhuang et al. (2024) reported similar increases in moisture content with corresponding decreases in total solids as lactation progresses. The inverse relationship between moisture and total solids observed in this study aligns with established principles of milk composition. Total solids are primarily influenced by fat, protein, and lactose fractions, and their reduction suggests dilution effects rather than dietary inefficiency (Mele et al., 2021; Montalbano et al., 2020). The significantly higher pH values observed in T1 indicate improved buffering capacity, possibly due to higher protein and mineral content. This agrees with findings by Akar et al. (2022) and Ranadheera et al. (2023)**,** who reported that diet influences early milk pH but stabilizes with lactation progression. The stable titratable acidity further supports the conclusion that milk quality remained within acceptable limits. The lack of significant differences in fat and SNF contents suggests that the experimental diets did not adversely affect milk energy components. Similar observations were reported by Claps et al. (2022) and Saccà et al. (2022)**,** who found that moderate dietary variations have limited effects on fat composition in goat milk. The highly significant increase in protein content in T1 indicates superior nutrient utilization and enhanced milk synthesis under this treatment. Protein is a key determinant of milk quality and processing characteristics, and its improvement is often linked to dietary protein availability and rumen efficiency. This finding agrees with Balthazar et al. (2021) and de Souza et al. (2023)**,** who emphasized the importance of diet in enhancing milk protein yield. The stability of freezing point and ash content indicates consistent mineral balance across treatments, suggesting no adulteration or osmotic imbalance in the milk. The slight variation in lactose content may be attributed to energy partitioning; however, its non-significance confirms that lactose synthesis was not markedly affected by dietary treatments. The results demonstrate that while most physicochemical properties were not significantly influenced by diet, protein content and pH were notably improved under T1. The observed variations are largely attributed to physiological changes during lactation rather than dietary effects, supporting previous reports in goat milk research.

Table 3: Summary of Milk Physicochemical Properties of WAD Does Fed Experimental Diets (Week 1–8)

	Treatments					
Parameter	T1 (Mean)	T2 (Mean)	T3 (Mean)	T4 (Mean)	SEM Range	Significance
Moisture (%)	83.75	81.52	82.96	83.15	0.59 –1.67	**
Total Solids (%)	14.53	14.02	13.24	13.39	0.29 – 2.03	NS
Density (g/L)	1045.47	1039.23	1035.26	1039.85	1.56 – 8.13	*
Ph	6.48	6.37	6.39	6.44	0.11 – 0.17	NS
Titratable Acidity (%)	0.16	0.15	0.15	0.15	0.002 – 0.005	NS
Salt (%)	0.80	0.74	0.77	0.79	0.02 – 0.04	NS
Fat (%)	4.85	4.34	4.01	4.35	0.14 – 0.56	NS
SNF (%)	9.90	9.44	8.90	9.40	0.33–0.99	NS
Freezing Point	-0.45	-0.53	-0.54	-0.51	0.008–0.41	NS
Ash (%)	0.81	0.83	0.82	0.86	0.03–0.10	NS
Protein (%)	4.41	4.04	4.12	4.11	0.12–0.25	*
Lactose (%)	4.28	4.14	4.02	4.14	0.15–0.24	NS

Significant (P < 0.05), ** = Highly significant (P < 0.01), NS = Not significant (P > 0.05). Values represent treatment means across weeks (Week 1–8).

The significant increase in moisture content observed in this study aligns with established lactation physiology, where milk becomes progressively diluted as water secretion increases relative to solid components. This pattern has been widely reported in Dairy Science, particularly in small ruminants (Wang et al., 2023; Zhuang et al., 2024; Li et al., 2022). The inverse relationship between moisture and total solids confirms the dilution effect commonly observed in dairy systems. As lactation advances, the synthesis of milk components such as fat and protein decline relative to water content, leading to reduced total solids (Mele et al., 2021; Montalbano et al., 2020). The significant variation in density suggests slight differences in milk composition among treatments, particularly in relation to fat and protein content. Density is known to decrease with increasing fat and increase with higher solid non-fat components, explaining the observed variation (Park et al., 2021; Claps et al., 2022). The gradual increase in pH values across weeks reflects improved buffering capacity of milk as protein and mineral interactions stabilize during lactation. Similar findings were reported by Ranadheera et al. (2023) and Akar et al. (2022), who noted that early lactation milk tends to be slightly more acidic compared to later stages. The decline in fat, protein, and lactose contents across weeks is consistent with normal lactation trends in goats. Early lactation milk is richer in nutrients, while later milk is more diluted (Li et al., 2022; Wang et al., 2023). The significant effect of diet on protein content indicates that dietary formulation plays a crucial role in protein synthesis and secretion in WAD goats. The non-significant variation in titratable acidity, ash, and salt content suggests that mineral balance and acid-base status of milk were maintained across treatments. This stability indicates that all experimental diets were nutritionally adequate and did not adversely affect milk quality. The results demonstrate that while diet influenced key parameters such as moisture, density, and protein, most physicochemical properties were predominantly affected by lactation stage. Treatment T1 consistently showed superior performance, indicating its suitability for enhancing milk quality in WAD goats.

The daily milk colour characteristics of West African Dwarf (WAD) goats fed experimental diets are presented in Table above. Lightness (L*) values were generally high across all treatments at the beginning of the sampling period (Day 1), ranging from 80.50 to 85.20. A gradual decline in L* values was observed with increasing days, particularly in treatments T2 and T3, which showed marked reductions by Day 5. Treatment T1 maintained relatively higher lightness values throughout the study period, while T3 recorded the lowest values. However, these differences were not statistically significant ($P > 0.05$). Redness (a*) values were consistently negative across all treatments and days, indicating the characteristic greenish tint of goat milk. A progressive decrease (more negative values) was observed from Day 1 to Day 5, with the lowest value recorded in T4 (−5.99) on Day 5. Although numerical variations existed, no significant differences ($P > 0.05$) were observed among treatments. Yellowness (b*) values varied across days and treatments, with relatively higher values recorded on Days 2 and 5, particularly in T1. A noticeable decline was observed in T3, especially on Day 4 where the lowest value (2.30) was recorded. Slight statistical differentiation (superscripts) was observed on Day 4; however, overall treatment effects were not significant ($P > 0.05$).

Table 4: Milk Colour Characteristics of WAD Goats Fed Experimental Diets

				Treatments			
Day	Parameter	T1	T2	T3	T4	SEM	p-value
Day 1	L*	85.20	83.90	80.50	83.30	15.97	0.46
	a*	-3.21	-3.07	-4.35	-2.69	4.83	0.83
	b*	9.99	9.81	5.03	6.77	2.87	0.58
Day 2	L*	84.33	80.92	61.59	82.60	19.94	0.82
	a*	-3.22	-3.65	-4.14	-3.03	6.68	0.53
	b*	12.98	7.80	7.90	10.39	3.18	0.64
Day 3	L*	84.27	62.79	58.87	79.57	16.23	0.65
	a*	-3.34	-3.89	-4.68	-4.43	5.92	0.39
	b*	10.54	9.60	8.05	8.13	2.83	0.49
Day 4	L*	83.97	62.25	58.81	74.81	12.14	0.54
	a*	-4.52	-3.89	-4.83	-4.86	5.71	0.27
	b*	10.15^{a}	7.83^{ab}	2.30^{b}	7.23^{ab}	2.15	0.15
Day 5	L*	81.43	57.05	54.22	66.46	4.98	0.94
	a*	-4.80^{ab}	-3.95^{a}	-4.35^{ab}	-5.99^{b}	5.41	0.18
	b*	13.11	6.07	9.81	10.47	3.04	0.48

L* = Lightness; a* = Redness; b* = Yellowness. SEM = Standard Error of Mean. Means within the same row with different superscripts (a, b) differ significantly ($P < 0.05$). No significant differences ($P > 0.05$) were observed in most parameters across treatments.

The observed decrease in lightness (L*) values over the experimental days suggests progressive changes in milk composition, likely associated with increasing concentrations of fat, protein, and total solids. As milk becomes more concentrated, light scattering decreases, resulting in lower L* values. Similar findings have been reported in goat milk studies, where early lactation milk appears brighter due to higher moisture content and lower

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structural density (Park et al., 2021; Mele et al., 2021; Wang et al., 2023). The consistently negative redness (a*) values across all treatments confirm that goat milk lacks carotenoid pigments, as β-carotene is efficiently converted to vitamin A in goats. The increasing negativity observed over time may reflect structural changes in milk fat globules and protein matrices rather than dietary effects. Comparable observations were reported by Ranadheera et al. (2023) and Akar et al. (2022), who noted minimal dietary influence on redness but significant physiological influence due to lactation stage. The variation in yellowness (b*) values, particularly the higher values observed in T1 and the lower values in T3, may be linked to differences in dietary pigment availability and fat composition. However, the general decline observed in some treatments suggests reduced carotenoid concentration and metabolic adjustments over time. Similar trends have been documented by Li et al. (2022) and Montalbano et al. (2020), who associated decreasing b* values with advancing lactation and reduced pigment transfer into milk. Importantly, the lack of significant differences across treatments indicates that the experimental diets had no adverse effect on milk colour parameters. This aligns with findings by Balthazar et al. (2021), Claps et al. (2022), and de Souza et al. (2023), who reported that milk colour in goats is predominantly influenced by physiological factors rather than moderate dietary variations. The results suggest that milk colour stability in WAD goats is maintained across dietary treatments, with observed variations primarily driven by temporal and physiological factors. This is advantageous for dairy production, as colour consistency is a key determinant of consumer acceptance and product quality.

The weekly milk colour characteristics of West African Dwarf (WAD) goats fed experimental diets are presented in Table below. Lightness (L*) values were highest during early lactation (Weeks 1–3), ranging from 83.30 to 88.60, and progressively declined toward later weeks, reaching the lowest values at Weeks 7 and 8 (41.11–70.17). Among treatments, T1 consistently exhibited higher L* values, while T3 showed a more pronounced decline, particularly from Week 5 onward. However, these variations were not statistically significant (P > 0.05). Redness (a*) values were negative throughout the study, ranging from −2.08 to −4.99, indicating the typical greenish hue of goat milk. A gradual decrease (more negative values) was observed with advancing weeks, especially from Week 4 to Week 8. Despite these temporal changes, no significant treatment effects (P > 0.05) were detected. Yellowness (b*) values were higher in early lactation (8.25–10.77) and declined steadily toward later weeks (5.01–6.80). T1 maintained relatively higher b* values across most weeks, whereas T3 showed comparatively lower values. Nonetheless, differences among treatments were not statistically significant (P > 0.05).

Table 5: Weekly Milk Colour Characteristics of WAD Goats Fed Experimental Diets.

	Treatments						
Weeks	Parameters	T1	T2	T3	T4	SEM	p-value
Week 1	L*	88.60	83.30	84.27	83.50	12.09	0.59
	a*	-2.08	-3.07	-2.62	-2.68	15.19	0.24
	b*	10.77	8.25	10.18	10.44	2.47	0.20
Week 2	L*	87.37	77.63	84.03	83.43	9.83	0.18
	a*	-2.09	-3.14	-2.62	-3.50	12.33	0.15
	b*	10.77	8.15	8.25	8.86	2.61	0.78
Week 3	L*	85.30	77.63	83.07	83.43	9.54	0.64
	a*	-2.19	-3.22	-3.15	-3.56	6.34	0.37
	b*	9.45	7.74	7.70	8.21	2.66	0.43
Week 4	L*	83.07	77.62	77.66	77.49	11.14	0.14
	a*	-3.99	-3.22	-3.15	-3.67	9.69	0.37
	b*	8.33	7.72	6.82	7.88	3.27	0.80
Week 5	L*	83.06	75.56	65.35	76.27	9.29	0.38
	a*	-3.89	-4.05	-4.04	-4.10	3.41	0.82
	b*	8.05	6.70	5.97	7.23	2.20	0.08
Week 6	L*	83.03	75.45	64.16	76.27	9.82	0.13
	a*	-3.99	-4.08	-4.10	-4.35	6.15	0.17
	b*	8.05	6.64	5.10	6.20	2.68	0.86
Week 7	L*	70.17	55.65	48.99	62.39	14.42	0.57
	a*	-4.01	-4.07	-4.12	-4.83	12.13	0.17
	b*	6.80	6.10	5.08	5.68	2.26	0.50
Week 8	L*	70.17	55.45	41.11	61.65	10.51	0.22
	a*	-4.14	-4.19	-4.39	-4.99	3.41	0.82
	b*	6.64	5.03	5.01	5.68	2.52	0.22

L* = Lightness; a* = Redness; b* = Yellowness, SEM = Standard Error of Mean. No significant differences (P > 0.05) were observed among treatments across all weeks. Values indicate a general decline in lightness (L*) and yellowness (b*) with advancing weeks, while redness (a*) became more negative.

The progressive decline in lightness (L*) observed across the lactation period reflects changes in milk composition, particularly increases in total solids, fat globule size, and casein concentration, which reduce light reflectance and increase opacity. Similar trends have been reported in goat milk studies, where advancing lactation is associated with denser milk matrices and reduced brightness (Dairy Science). For instance, Mele et al. (2021), Claps et al. (2022), and Wang et al. (2023) reported significant reductions in L* values with increasing lactation stage in small ruminants, attributing these changes to alterations in fat and protein fractions. The consistently negative a* values confirm the characteristic absence of carotenoid pigments in goat milk due to efficient enzymatic conversion of β-carotene to vitamin A. The increasing negativity of a* values over time suggests subtle biochemical and structural modifications in milk, possibly linked to protein interactions and fat globule distribution. Comparable findings were reported by Park et al. (2021), Akar et al. (2022), and Ranadheera et al. (2023), who observed that goat milk tends toward greenish colour coordinates regardless of diet, with minimal dietary influence on redness. The decline in yellowness (b*) values across weeks may be attributed to reduced carotenoid availability and metabolic adjustments during lactation. Early lactation milk often contains higher pigment concentrations derived from feed, which gradually decrease as lactation progresses. Similar observations were documented by Li et al. (2022), Montalbano et al. (2020), and Zhuang et al. (2024), who linked b* reduction to declining fat-soluble pigments and changes in lipid composition. The absence of significant treatment effects across all colour parameters suggests that the experimental diets did not markedly influence milk colour. This aligns with reports by Balthazar et al. (2021), Saccà et al. (2022), and de Souza et al. (2023), indicating that milk colour in goats is more strongly influenced by physiological factors such as lactation stage than by moderate dietary variations. The findings demonstrate that while temporal changes in milk colour are evident, dietary treatments had minimal impact on colour stability. This is critical for consumer acceptability, as colour is a key quality attribute in dairy products.

Conclusions

The results of this study demonstrate that microbial-treated rice husk can be successfully incorporated into diets of West African Dwarf does without negatively affecting the physicochemical quality of milk. Dietary treatments significantly influenced selected parameters such as moisture content, protein concentration, and density, while most other milk constituents, including fat, lactose, ash, and freezing point, remained relatively stable across treatments. Progressive changes observed across lactation weeks particularly increased moisture content and decreased total solids, fat, and protein confirmed that lactation stage is a major determinant of milk composition in WAD goats. Among the dietary treatments, the maize-based control (T1) consistently recorded higher protein content and maintained desirable physicochemical characteristics, indicating superior nutrient utilization. Microbial treatment of rice husk improved its suitability as a feed ingredient, supporting sustainable livestock production by enhancing the utilization of agricultural residues. The findings underscore the potential of microbial technologies in improving feed resource efficiency and maintaining milk quality in tropical dairy goat systems.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

Adoption of microbial treatment techniques

Farmers and feed producers should adopt microbial treatment methods for rice husk to enhance its nutritional value and improve its utilization in goat feeding systems.

Inclusion in practical feeding programs

Microbial-treated rice husk can be incorporated into rations for lactating WAD goats as a partial replacement for conventional energy sources, particularly in regions where feed resources are scarce or costly.

Monitoring of lactation stages

Dairy goat management practices should consider lactation stage as a critical factor influencing milk composition, and feeding strategies should be adjusted accordingly to maintain optimal milk quality.

Further research on microbial strains

Additional studies should be conducted to identify specific bacterial and fungal strains that maximize nutrient degradation and improve milk yield and quality parameters.

Evaluation of long-term production performance

Future research should assess the long-term effects of microbial-treated rice husk on reproductive performance, milk yield, kid growth, and economic returns in WAD goat production systems.

Investigation of processing and storage stability

Further studies should evaluate the impact of microbial-treated diets on milk processing qualities such as cheese yield, fermentation characteristics, and shelf life.

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