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EFFECTS OF FEEDING DRIED ORANGE PULP FORTIFIED WITH AND WITHOUT PROBIOTIC (*SACCHAROMYCES CEREVISIAE*) ON GROWTH PERFORMANCE, LIPID METABOLISM, AND OXIDATIVE STRESS BIOMARKERS IN RED SOKOTO GOATS

[1]Sani, M. U., [2]Bitrus, I. M[*]., [1]Ishaya, W. W., [1] Mbahi, T. F., and [3]Odenigbo, G.

[1]Department of Animal Science, Taraba State University, Jalingo, Taraba state
[2]Department of Animal Health and Production, University of Benin, Benin City, Nigeria
[3]Department of Veterinary Pathology, University of Benin, Benin City, Nigeria.
[*]***Correspondence email and contact***: ishaku.manang@uniben.edu.ng

ABSTRACT

This study examined the effects of feeding 30% dried orange pulp (DOP), both with and without the probiotic *Saccharomyces cerevisiae*, on the growth performance, lipid metabolism, and oxidative stress indicators of Red Sokoto goats. Four dietary treatments (T1: Control; T2: 0% DOP + 1% Probiotic; T3: 30% DOP without Probiotic; T4: 30% DOP + 1% probiotic) were randomly assigned to twelve goats, aged four to five months in a feeding experiment lasting 70 days. The result revealed that DOP successfully replaced traditional energy source maize offal. Although initial and end body weights varied greatly, there were no significant variations in overall weight gain, feed intake, or feed conversion ratio between treatments. Notably, showing the lowest levels of triglycerides and total cholesterol, the combination of 30% DOP and probiotics (T4) greatly enhanced lipid regulation. DOP inclusion up to 30% did not compromise antioxidant defence mechanisms, as shown by the lack of significant changes in oxidative stress indicators (MDA, GPx, and CAT). According to the findings of this study, dried orange pulp is a sustainable and nutritious substitute feed source that can provide Red Sokoto goats with extra metabolic advantages when combined with probiotics in their feed rations.

Key Words: Red Sokoto Goats, Dried Orange Pulp, Probiotics, Lipid Metabolism, Oxidative Stress, Citrus byproducts

INTRODUCTION

The Red Sokoto goat, also known as the Maradi, is one of the most popular native goat breeds in Nigeria and sub-Saharan Africa. They are valued for their superior skin quality, ability to withstand harsh tropical weather, and important contribution to livelihoods in urban and rural areas through meat, revenue, and sociocultural activities. Despite these benefits, nutritional limitations, rising costs of conventional concentrate feed ingredients, and a shortage of high-quality forages, particularly during dry seasons, prevent Red Sokoto goats from reaching their full genetic and productive potential (Bampidis and Robinson, 2006). These challenges necessitate the search for sustainable, affordable, and high-quality feed choices that maintain animal performance without raising production costs.

Because of their year-round availability, low cost, and compatibility with rumen fermentation, agro-industrial by-products are the most promising feed sources for ruminants. Their use promotes a circular bioeconomy, increased animal production and environmental sustainability (Guzmán *et al.*, 2024; Habeeb, 2023). By-products of orange are gaining popularity as feed additives for ruminants all over the world. The pulp can be fed fresh, crushed, dried, or pelleted (Guzmán *et al.,* 2024). Flavonoids, carotenoids, polyphenols, and dietary fibre are among the nutritional and useful bioactive compounds found in citrus peels and pulps, yet they are often discarded (Guzmán *et al.,* 2021). Because of their high pectin content and fermentable neutral detergent fibre (NDF), they are ideal substrates for rumen microorganisms and have less detrimental effects on rumen cellulolysis compared to supplements high in sugar or starch. They improve the digestibility of fibre while maintaining the digestion of dry matter and organic matter by replacing starchy substances (Habeeb *et al.,* 2017).

Probiotics are used as feed supplements in animal production systems all over the world. They are also used in ruminant nutrition to improve animal health and productivity, regulate rumen fermentation, and encourage nutrient utilisation (Chaucheyras-Durand *et al*., 2008; Mountzouris, 2009). Probiotics enhance immunological responses, lower gut pH, create antimicrobials, lower amounts of ammonia and harmful amines, and improve feed and carbohydrate digestibility (Markowiak and Śliżewska, 2018). In the rumen and intestinal microbiota, they also reduce harmful bacteria and increase beneficial microbial populations (Zsóka *et al.,* 2022; Musa, 2009). Probiotics enhance lipid metabolism, oxidative balance, and immune function in small ruminants through rumen stability and metabolic regulation (Muhammed *et al.,* 2018). When combined with uncommon feed resources like citrus by-products, probiotics can minimise anti-nutritional effects, boost fermentability, and maximise nutritional and functional value. It is necessary to assess how orange pulps affect goat productivity. Thus, the purpose of this study is to evaluate the effects on growth performance, lipid metabolism, and oxidative stress indicators in Red Sokoto Goats of feeding orange pulps fortified with and without probiotics (*Saccharomyces cerevisiae).*

MATERIALS AND METHODS

Experimental Site: This study was carried out at the Livestock Unit of the Teaching and Research Farm of the Department of Animal Science, Taraba State University Jalingo.Jalingo is located in the north eastern part of Nigeria.The city is about 583 km Northeast of Abuja with an elevation of about 239.82 meters above sea level. According to Oruonye and Ojeh (2018), Jalingo is located between Latitude 8° 47' N 9º 01' N and Longitude 11° 09' E, 11° 30' E . It covers land area of approximately 195.07 km² andthe region experiences an average annual temperature of 27.9°C and rainfall of 958 mm (Oruonye, 2014).

Collection and Processing of Dried Orange Pulp (DOP): Fresh orange pulp, comprising peel, pulp, and seeds, was acquired from local fruit merchants in Jalingo city. The harvested pulps were promptly transported to the farm for processing to prevent fermentation and spoilage. The pulps were evenly distributed on clean tarpaulins and sun-dried at about the average temperature of 27.9ºC for 5 to 7 days until the moisture content was reduced to around 10% (Bampidis and Robinson, 2021). The dehydrated material was ground with a hammer mill to reduce the particle size to around 2mm, ensuring homogeneous mixing with other nutritional components of the experimental diets. Upon completion of the processing of dried orange pulp, the product was stored in tightly sealed bags in a cool, dry environment to preserve its nutritional integrity and inhibit mould proliferation.

Source and Preparation of probiotion of Probiotic: A commercial active dry yeast (*saccharomyces cerevisiae*) obtained from UltraMix probiotic, with a viability of approximately 1.0 x 10^9 CFU/g was used as a probiotic. The yeast was premixed with a small portion of concentrate and subsequently incorporated into the basal diet containing dried orange pulp to ensure uniform distribution. The diets were prepared fresh daily and offered immediately to maintain viability of the yeast cells

Experimental Design, Management and Diets: Twelve Red Sokoto goats between the ages of four and five months were used for this study. The goats were purchased from flocks owned by traditional goat keepers in the village market settlements of Mutumbiyu in the Gassol Local Government Area of Taraba state and Iware in the Ardo-Kola local government Local Government. After their arrival, the animals were kept for two weeks in the livestock section of the Teaching and Research Farm of the Department of Animal Science at Taraba State University Jalingo. In order to prevent gastrointestinal parasites that are known to be endemic in the study location, the animals were weighed and de-wormed with albendazole. *Pested des petit* ruminants (PPR) vaccination purchased from the National Veterinary Research Institute (NVRI), Vom, Plateau state, was also administered. The 12 goats were randomly assigned to four treatment groups after two weeks of acclimatization. Each treatment group consisted of three (3) goats and replicated three times, with a goat representing a replicate, using a Completely Randomized Design (CRD). To enable accurate assessment of each animal's feed intake, the animals were kept in separate pens with feeding and watering troughs. The following is how the experimental diets were set up:

T1: Mixed ration + 0% DOP without probiotics (Control).

T2: Mixed ration + 30% DOP without probiotics.

T3: Mixed ration + 0% DOP + 1% Probiotics.

T4: Mixed ration + 30% DOP + 1% Probiotics.

Where, T1, T2, T3 and T4 represent the four treatment groups of the experiment.

Table 1: Experimental diet containing probiotic-fortified and unfortified dried orange pulp.

	Treatments			
Ingredients	**T1 (P0)**	**T2 (P0)**	**T3 (P1)**	**T4 (P1)**
Maize offal (%)	40	10	40	10
Ficus sycomorus leaves (%)	35	35	35	35
Cowpea Husks	6.2	6.2	6.2	6.2
Dry Orange Pulp (%)	00	30	00	30
Soyabean Meal (%)	15	15	15	15
Mineral Supplements (%)	2	2	2	2
Vitamin Supplements (%)	0.5	0.5	0.5	0.5
Salt (%)	0.5	0.5	0.5	0.5
Calcium (%)	0.5	0.5	0.5	0.5
Phosphorus (%)	0.3	0.3	0.3	0.3
Total	**100**	**100**	**100**	**100**
Calculated analysis				
Crude Protein (CP) (%)	14.0	14.0	14.0	14.0
Metabolisable Energy (ME) Mcal/kg	2.2	2.2	2.2	2.2
Acid Detergent Fiber (ADF) (%)	25.0	28.0	25.0	28.0
Neutral Detergent Fiber (NDF) (%)	35.0	38.0	35.0	38.0
Calcium (%)	0.5	0.5	0.5	0.5
Phosphorus (%)	0.3	0.3	0.3	0.3

P0= 0% probiotic and P1= 1% probiotic.

Proximate Analysis: Experimental feed sample (dried orange pulps) were grounded using a hammer mill to pass through a sieve of 1 mm diameter and were analyzed for dry matter (DM) content, crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), total ash, crude fiber (CF), acid detergent fibre and neutral detergent fibre using AOAC (2000) procedures. Acid detergent fibre and neutral detergent fibre were determined based on the methods described by Vansoest, (1994).

Data Collection

Growth Performance:

Feed Intake: A known quantity of feed was offered twice daily at 8:00 am and 4:00 pm. The quantity of feed refused was collected and weighed the following morning before the subsequent feeding. Daily feed intake was calculated as the difference between the feed offered and the feed refused.

Body Weight Gain: Animals were weighed at the start of the experiment for the initial body weight and subsequently on a weekly basis before the morning feeding, using a spring balance. The average daily gain (ADG) was calculated by dividing the total weight gain by the duration of the feeding trial (70 days).

Feed conversion ratio (FCR): This was determined by dividing the total dry matter intake by the total weight gain.

Blood Collection for Lipid Profile and Oxidative Stress: At the end of the 70-day trial, blood samples (10 ml) were collected from each goat via jugular vein, using sterile needles. Samples for serum analysis were collected in plain tubes and were allowed to coagulate, and centrifuged at 3000 rpm for 15 minutes. The harvested serums were stored at -20°C until analysis.

Lipid Profile: For lipid Metabolism, the serum was analyzed for total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) as described by Yeom *et al*. (2002), using automatic analyzer (Automatic analyzer 902, Hitachi, Germany).

Oxidative Stress: For the assessment of antioxidant status on oxidative stress biomarkers, serum was analyzed for the activity of superoxide dismutase (SOD) and catalase (CAT) by the Hydroxylamine method (Weydert and Cullen, 2010). Lipid peroxidation was quantified by measuring Malondialdehyde (MDA) levels using the thiobarbituric acid reactive substances (TBARS) as described by Draper and Hadley (1990).

Statistical Analysis: All data generated from this study were subjected to a One-way Analysis of Variance (ANOVA) using the SAS (2004) Statistical Software. Where significant differences occurred, means were separated using Duncan's Multiple Range Test at a 5% level of significance (Duncan, 1955).

RESULTS AND DISCUSSIONS

Growth Performance: The growth performance of Red Sokoto goats fed orange pulps supplemented with and without probiotics is displayed in Table 2. While weight gain, feed intake, and feed conversion ratio did not differ significantly (P>0.05) between treatments, beginning and ultimate body weights did. The highest final weight (13.10 kg) and weight gain (2.50 kg) were shown by the treatment with 30% DOP supplemented with 1% *Saccharomyces cerevisiae* (probiotic), suggesting the best synergistic effects of probiotics and dried orange pulp. According to Okpara *et al.* (2024), "citrus by-product supplementation in small ruminant diets, combined with probiotics, resulted in enhanced growth performance through improved nutrient utilisation and gut health." The results of this study are consistent with their findings. Contrary to certain previous findings about the palatability of citrus pulp, the absence of clear and significant differences in feed intake among the treatment groups may indicate that the diet is palatable.

In the current investigation, there was no significant (P>0.05) difference in feed conversion ratios between the treatment groups. But the highest effective feed utilisation was shown by the treatment group that received 30% DOP plus 1% *Saccharomyces cerevisiae* (probiotic). This conclusion is consistent with research by Omogbenigun *et al.* (2004), which found that probiotic supplementation significantly improves feed efficiency in goats fed alternative energy sources by altering nutrient digestibility and rumen microbial activity. Similarly, Inweh *et al.* (2022) found that adding citrus waste products to the ration at inclusion levels ranging from 15% to 25% increased growth rates in West African dwarf goats. This study's equivalent weight gains (2.14 to 2.50 kg) can be explained by the fact that dried orange pulp can successfully replace maize offal with little detrimental impact on animal productivity. This conclusion is consistent with the findings of Sharif *et al.* (2018), who found that when appropriately processed and supplemented, citrus pulp provides a sufficient energy supply for ruminant feeding.

The results of this study showed that T4 initial and final weights were much higher than those of the other treatments, indicating that the probiotics and orange pulp had a synergistic impact that improved growth. Similar patterns were seen by Yusuf *et al.* (2019) in Yankasa sheep fed diets with probiotic-enriched citrus peel meal, which led to increased weight growth. One of the main issues with using citrus by-products in ruminant animal nutrition was addressed because there were no discernible changes in feed consumption across the treatment groups, suggesting that the animals accepted the orange pulp-based diets.

Table 2. Growth Performance of Red Sokoto goat fed dried orange pulp with and without probiotic

	Without Probiotics		With Probiotics			
	T1 (0% DOP)	T2 (30% DOP)	T3 (0%DOP)	T4 (30%DOP)	SEM	P-Value
Parameters						
Initial Weight (kg)	6.97^{c}	9.23^{ab}	8.97^{b}	10.60a	0.416	0.000
Final Weight (kg)	9.30^{c}	11.37^{b}	11.27^{b}	13.10a	0.417	0.000
Weight Gain (kg)	2.33	2.14	2.30	2.50	0.081	0.514
Feed Intake (kg)	25.55	28.50	25.70	27.70	0.595	0.206
Feed Conversion Ratio	10.96	13.32	11.17	11.08	4.321	0.519

DOP: Dry orange pulp, SEM: Standard error of mean, Superscripts a,b,c in the same row shows a significant difference in the Means (p<0.05).

The results in Table 3 revealed that dietary inclusion of dried orange pulp (DOP) with or without probiotics significantly (P < 0.05) influenced the serum lipid profile of Red Sokoto goats. These variations reflect the role of diet composition and gut-modulating additives in lipid metabolism.Total cholesterol (TCHOL) was significantly reduced in goats fed 30% DOP without probiotics (T3; 1.60), followed by T4 (2.27), compared to the control (T1; 3.50). This reduction suggests that DOP inclusion improved lipid metabolism, likely due to its high content of soluble fibre and bioactive compounds such as flavonoids, which are known to reduce cholesterol absorption and enhance lipid utilization. Similar findings were reported by Bampidis and Robinson (2006), who observed that citrus by-products reduce serum cholesterol in ruminants through improved rumen fermentation and fibre digestion.

Triglyceride (TG) concentration differed significantly (P<0.05) among treatments, with T4 (1.03) recording the highest value, while T3 (0.27) had the lowest. The elevated TG level in T4 (DOP with probiotics) may be attributed to increased lipid mobilization or altered rumen fermentation patterns associated with probiotic activity. Probiotics are known to influence lipid metabolism by modifying microbial populations and enhancing nutrient absorption, which can sometimes increase circulating triglycerides depending on dietary composition (Uyeno *et al.,* 2015). Conversely, the lower TG observed in T3 supports the beneficial effect of DOP alone in reducing circulating lipids.

High-density lipoprotein (HDL) values were significantly higher (P<0.05) in T1 (2.03) and T2 (1.83) compared to T3 (1.03) and T4 (0.77). Although HDL is considered beneficial due to its role in reverse cholesterol transport, the reduction observed in DOP-based diets may be linked to overall decreased lipid availability in circulation. This aligns with reports ofGhasemi *et al.* (2018) "that high-fibre diets can reduce both total cholesterol and HDL levels due to decreased lipid absorption".

Similarly, low-density lipoprotein (LDL) concentrations followed the same trend as HDL, with higher values in T1 (2.03) and T2 (1.83) and significantly (P<0.05) lower values in T3 (1.03) and T4 (0.77). The reduction in LDL with DOP inclusion is desirable, as LDL is associated with cholesterol transport and deposition in tissues. This finding supports earlier reports that dietary fibre from agro-industrial by-products can reduce LDL levels by binding bile acids and promoting cholesterol excretion (Bampidis and Robinson, 2006).

Very low-density lipoprotein (VLDL) levels also varied significantly (P<0.05), with T4 (0.47) recording the highest value and T2 (0.10) the lowest, while T3 (0.17) and T1 (0.27) showed intermediate values. Since VLDL is closely associated with triglyceride transport, the elevated value in T4 corresponds with its higher TG concentration. This suggests that probiotic supplementation in combination with DOP may enhance lipid transport mechanisms, possibly through increased hepatic synthesis or mobilization of triglycerides (Uyeno *et al.,* 2015).

Lipid Profile

Table 3: Lipid Profile of Red Sokoto Goats Fed DOP with and without Probiotics

	Treatment				SEM	P. Value
	T_1 (P0%)	T_2 (P0%)	T_3 (P1%)	T_4 (P1%)		
Parameters						
Total Cholesterol (TCHOL)	3.50^{a}	3.10^{ab}	1.60^{c}	2.27^{bc}	0.24	0.002
Triglycerides (TG)	0.57^{b}	0.33^{bc}	0.27^{c}	1.03^{a}	0.09	0.000
High – Density Lipoproteins (HDL)	2.03^{a}	1.83^{a}	1.03^{b}	0.77^{b}	0.09	0.001
Low Density Lipoproteins (LDL)	2.03^{a}	1.83^{a}	1.03^{b}	0.77^{b}	0.09	0.001
Very Low-density Lipoproteins (VLDL)	0.27^{b}	0.10^{c}	0.17^{bc}	0.47^{a}	0.04	0.000

DOP: Dry orange pulp, SEM: Standard error of mean, Superscripts a,b,c in the same row shows a significant difference in the Means (p<0.05).

Oxidative stress: The oxidative stress profile presented in Table 4 shows no significant (P>0.05) variation in Malondialdehyde (MDA), Glutathione Peroxidase (GPx), and Catalase (CAT) across the dietary treatments. MDA values ranged from 1.2879 in the control group (T1) to 2.3098 in T3. T2 recorded 2.1618, while T4 had 2.0096. Although the differences were not statistically significant (P>0.05), a clear numerical pattern of higher MDA in the treated groups compared to the control was observed. Interestingly, T3, which combined DOP and probiotics, recorded the highest MDA value. This suggests that the combination did not produce a synergistic antioxidant effect under the conditions of the study. Probiotics are generally associated with improved gut health and reduced oxidative stress, but their efficacy depends on strain type and diet interaction (Markowiak and Śliżewska, 2018).

MDA is a terminal product of lipid peroxidation and is commonly used as an index of oxidative damage. Lower concentrations generally indicate reduced oxidative stress. In this study, the lowest value in T1 suggests better membrane stability in goats fed the basal diet. The elevated values in the DOP-based diets imply a relative increase in lipid peroxidation. The higher MDA levels observed in the treatment groups suggest that inclusion of dried orange pulp (DOP), with or without probiotics, did not reduce oxidative stress. This outcome does not align with the expected antioxidant potential of citrus by-products, which are known to contain phenolic compounds and flavonoids with free radical scavenging properties (García *et al.,* 2020; Khan *et al.,* 2021).

GPx activity showed values of 26.1048 in T1, 32.2043 in T2, 38.9231 in T3, and 34.9983 in T4. Differences among treatments were not significant (P > 0.05). Even so, T3 displayed the highest numerical value. CAT followed a similar pattern, ranging from 3.2882 in T1 to 4.8161 in T4, also without significant (P > 0.05) differences. T4 recorded the highest catalase activity. Glutathione Peroxidase and Catalase function as primary enzymatic antioxidants. They act by neutralizing reactive oxygen species and maintaining cellular redox balance. Their activities often rise when animals are exposed to oxidative challenges. In the present study, however, the responses were not strong enough to indicate a clear dietary effect.

One possible explanation is ruminal degradation of bioactive compounds before absorption. Ruminant microbial activity can alter or break down polyphenols, reducing their systemic availability Vasta *et al.,* 2019). Dietary substitution of maize offal with DOP may also have changed energy balance in a way that slightly increased metabolic stress.

The slightly higher GPx in T3 and CAT in T4 may indicate a mild adaptive response. Still, these increases were not statistically significant, and therefore cannot be considered a strong physiological improvement. The pattern appears more compensatory than beneficial.

Table 4: Oxidative Stress Biomarkers of Red Sokoto Goats Fed DOP with and without Probiotics

	Treatments					
	T_1 (P0%)	**T_2 (P1%)**	**T_3 (P0%)**	**T_4 (P1%)**	**SEM**	**P. Value**
Parameters						
Malondialdehyde (MDA)	1.2879	2.1618	2.3098	2.0096	0.152	0.051
Glutathione Peroxidase (GPx)	26.1048	32.2043	38.9231	34.9983	2.301	0.265
Catalase (CAT)	3.2882	3.5847	4.2602	4.8161	0.291	0.260

SEM: Standard error of mean,

CONCLUSION

In conclusion, the findings demonstrate that dried orange pulp is a nutritionally effective, safe, and sustainable alternate feed resource for Red Sokoto goats. Its inclusion in the diet does not negatively affect growth performance or overall productivity, making it a viable substitute for part of conventional feed ingredients.

Additionally, the incorporation of probiotics provides further metabolic advantages, particularly in improving lipid profiles, which may enhance animal health and efficiency. The absence of oxidative stress indicators also confirms the safety of his feeding strategy.

Therefore, inclusion of dried orange pulp at levels up to 30% can be recommended as a cost-effective feeding approach, especially during periods of forage scarcity. When combined with probiotics, offers added nutritional and metabolic benefits, supporting both productivity and sustainability in goat production systems

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