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Research Article

Keywords: Rabbits, Soaked Sorrel Seed Meal, Growth Performance, Nutrients digestibility

Posted Date: October 7th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10908717/v1

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Effect of Partial Replacement of full Fat Soya with Soaked Sorrel *(Hibiscus sabdariffa* L.) Seed Meal in the Diet of Weanling Rabbit

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Abstract

This study evaluated the effect of partial replacement of full-fat soybean with room-temperature soaked sorrel seed meal (RTSSM; *Hibiscus sabdariffa* L.) on the growth performance and nutrient digestibility of weanling rabbits. The experiment was conducted in 2023 at the Rabbitry Unit of the University of Ibadan Teaching and Research Farm, Oyo State, Nigeria. Seventy-five weanling rabbits, aged 6–7 weeks and weighing 623 ± 0.53 g, were randomly allotted to five dietary treatments in a completely randomized design, with 15 rabbits per treatment, for 10 weeks. The experimental diets were isonitrogenous and formulated to meet or exceed NRC (2012) nutrient requirements. RTSSM replaced full-fat soybean at 0% (T1), 10% (T2), 20% (T3), 30% (T4), and 40% (T5). Feed and clean water were provided ad libitum. Significant differences ($p<0.05$) were observed in average daily weight gain (ADWG), feed conversion ratio (FCR), and protein efficiency ratio (PER), while average daily feed intake was comparable among treatments. Rabbits fed 0% RTSSM recorded the highest ADWG (12.25 g), comparable with those fed 10% RTSSM (9.01 g). The control diet also produced the best FCR (0.73) and PER (0.09), comparable with 10% RTSSM (1.01 and 0.06, respectively). Nutrient digestibility differed significantly ($p<0.05$), although dry matter digestibility was comparable across treatments. Crude protein and crude fibre digestibility were lowest at 40% RTSSM, while fat digestibility was reduced at 0% and 40% inclusion. Feed cost per kilogram was highest for the control diet. Overall, RTSSM can partially replace full-fat soybean in weanling rabbit diets, with 10% inclusion.

Keywords: Rabbits, Soaked Sorrel Seed Meal, Growth Performance, Nutrients digestibility.

Introduction

One potential unconventional protein source is the sorrel (*Hibiscus sabdariffa* L.) seed meal. Sorrel seeds contain an ideal nutritional profile, which is evidenced by their content of 93.50% dry matter, 21.75% crude protein, 7.79% ether extract, 6.50% crude fibre, and 39.22% nitrogen-free extract (Aliyu, 2020). Although raw sorrel seed meal has already been used as feed for broilers (Igwebuike *et al*., 2005; Kwari, 2009), processing is recommended to decrease the presence of antinutritional compounds like tannins, which adversely affect the growth and productivity of animals (Maikano *et al*., 2014). Processing techniques include heating, fermentation, and soaking (Kwari, 2009; Olaoye *et al*., 2023).

Rabbits possess an advanced ability than any other monogastric animal regarding utilizing the Non-Conventional Feed Resources (NCFR), which refer to dietary sources that are not commonly used in feed formulation, particularly agro-industry by-products as well as meals from tropical plants (Idahor, 2013). This reveals the nutritive value contained in the NCFR despite being underutilized due to poor knowledge about these feed sources.

Sorrel crop is found in West African areas where its leaves are eaten as vegetables, its calyces are made into a beverage known as Zobo, and its stems produce fiber. Though its seeds are of great importance in food for human consumption especially in certain countries like France and parts of West Africa, a considerable number of seeds are annually disposed of, in the farms of Nigeria (Duwa, 2012; Maikano, 2014).

Studies show that SSM is an excellent partial replacement for conventional protein sources in chicken feeds where the success of the use of the ingredient depends on processing techniques and replacement rates. Nyameh *et al*. (2012) investigated the replacement effect of GNC with SSM in broiler chickens. The results revealed that there was no effect on average daily gain, feed intake, and feed conversion ratio among the different treatment groups. Interestingly, broilers consuming raw SSM had the highest dressed weight. Thus, the conclusion drawn from the findings showed that SSM could be used to replace GNC by 50 percent without any negative effect on the performance of the broilers. In a similar study, Kwari *et al*. (2010) established that more than 50 percent replacement of SBM with raw SSM negatively impacted live weight gain and feed intake in broilers; hence, 50 percent replacement was recommended. Besides broilers, SSM can also be

utilized by layers. According to Kwari *et al*. (2011), there was no significant difference in feed efficiency, egg production, egg weight, eggshell thickness, and cost of feed when 50 percent of SBM was replaced with SSM.

There are considerable differences in nutrient digestibility in rabbits depending on their breed and strain, with meat breeds tending to have greater efficiencies (Church and Kellems, 1998). For example, New Zealand Whites are usually slightly more productive than Californians (Olaleru and Abu, 2021). Physiological variables play a part in digestibility, as evidenced by the reduced rates of growth and feeding after weaning, which tend to stabilise at nine weeks.

Digestion is determined by the ratio of nutrient breakdown speed to digesta retention time. While a slower transit through the caecum could lead to improved nutrient absorption, it would also raise the likelihood of developing digestive disorders. Thus, a faster transit process is more physiological in nature for rabbits. Furthermore, the overall level of feed intake can influence digestibility, underscoring the critical role of dietary management in optimising nutrient utilisation (Olaleru and Abu, 2021).

Materials and Methods

Experimental Site

The study was carried out at the University of Ibadan Teaching and Research Farm's Rabbitry Unit, which is situated at latitude 7.27 °N and longitude 3.54 °S on the Oyo State GPS in 2023.

Animal experimental design, and diets

A feeding trial was conducted over a ten-week period using seventy-five weanling rabbits with an initial average weight of 623 ± 0.53 g, aged six to seven weeks. The rabbits were randomly distributed into five dietary treatment groups in a completely randomised design (CRD), with fifteen rabbits per group. The experimental diets were formulated to be iso-nitrogenous and to meet or exceed the nutrient requirements for rabbits as established by the NRC (2012) as presented in Table 1. The treatments consisted of a control diet (T1) containing 0% soaked sorrel seed meal (SSM), and four test diets in which SSM was incorporated to replace other protein sources at inclusion levels of 10% (T2), 20% (T3), 30% (T4), and 40% (T5). Throughout the experimental

period, all rabbits were provided with ad libitum access to both feed and clean drinking water. All husbandry and management practices were conducted in accordance with standard laboratory protocols by the Animal Care and Use Research Ethics Committee (ACUREC) (2021).

Table 1 Gross Composition of sorrel seed-supplemented diets fed to weanling rabbits

Ingredients (%)	**SSM (0%)**	**SSM (10%)**	**SSM (20%)**	**SSM (30%)**	**SSM (40%)**
Maize	20.00	20.00	20.00	20.00	20.00
Full Fat Soya	16.00	14.40	12.80	11.20	9.60
Sorrel seed meal	0.00	1.60	3.20	4.80	6.40
Palm kernel cake	20.00	20.00	20.00	20.00	20.00
Cassava Meal	2.50	2.50	2.50	2.50	2.50
Fish Meal	1.00	1.00	1.00	1.00	1.00
Wheat Offal	20.00	20.00	20.00	20.00	20.00
Rice husk	15.00	15.00	15.00	15.00	15.00
Bone Meal	2.00	2.00	2.00	2.00	2.00
Lime Stone	3.00	3.00	3.00	3.00	3.00
*Premix	0.25	0.25	0.25	0.25	0.25
Table Salt	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Energy ME (kcal/kg)	2420.03	2367.60	2315.17	2262.74	2210.32
CP	18.30	18.08	17.82	17.58	17.30
CF	9.23	9.69	10.25	10.42	10.85
Feed cost/kg (₦)	216.83	212.38	208.38	204.39	200.39

**Premix: Vitamin and Trace Minerals Supplied the following additional Micro and Macro nutrient Premix: Cobalt = 0.20 mg; Zinc = 50 mg; Selenium = 0.20 mg; Iron = 20 mg; Iodine = 1.2 mg; Copper = 5 mg; Manganese = 80 mg; Antioxidant = 0.125 ppm; Vitamin E = 20 IU; Choline Chloride = 400 mg; Biotin = 50 mg; Pantothenic acid = 7.50 mg; Niacin = 27.50 mg; Vitamin A = 10,000 IU; Pyridoxine B6 = 2.75 mg; Vitamin D3 = 2,000 IU; Riboflavin B2 = 0.5 mg; Thiamine B1 = 1.75 mg; Vitamin K = 2.25 mg; CP: crude protein; CF: crude fibre; SSM: soaked sorrel seed meal*

Growth Performance and Nutrient Utilisation Indices

A comprehensive evaluation of growth performance and nutrient utilisation was conducted through a series of measured and calculated parameters. The primary growth metrics were determined as follows: Feed intake was quantified by providing 10 gramm and subtracting the leftovers collected the following morning. Weight gain was monitored by recording live weights at the commencement of the study and on a weekly basis thereafter. These two measurements were used to calculate the Feed Conversion Ratio (FCR), defined as the ratio of feed intake to weight gain, which serves as a key indicator of metabolic efficiency.

To specifically evaluate the quality of dietary protein, several indices were employed. The Protein Efficiency Ratio (PER) was computed as the total weight gain divided by the total protein intake. A more refined measure, the Net Protein Ratio (NPR), was also determined.

$$\text{NPR} = \frac{Weight\,gain\,of\ test\,group + Weight\,loss\,of\,NFD\ group}{\text{Pr}\,otein\,\text{int}\,ake\,of\ test\,group} \quad (1)$$

A nutrient digestibility trial was executed to determine the availability of dietary components. Following a 5-day adaptation period, total faecal output was collected from three randomly selected animals per treatment over a 5-day collection period. The collected faeces were air-dried, then oven-dried at 105 °C for 48 hours. Proximate composition of the feed and faecal samples was analysed according to standard procedures (AOAC, 2019). Apparent nutrient digestibility was subsequently computed for each nutrient using the formula:

$$\text{Nutrient digestibility} = \frac{\%\ Nutrient\,in\ feed\ x\ F1 - \%\ Nutrient\,in\ faeces\,x\ F0}{\%\ Nutrient\,in\ feed\ x\ F1}\,x\,100 \quad (2)$$

Where:

FI = Total feed intake during the collection period

FO = Total faecal output (dry matter basis) during the collection period

Result and Discussion

Growth Performance of Rabbits fed (26-28°C) Soaked Sorrel Seed Meals (RTSSSM)

The growth performance of rabbits fed of room temperature soaked sorrel seed meal is presented in Table 2. Significant differences ($p<0.05$) were observed in the average daily weight gain (ADWG), feed conversion ratio (FCR) and protein efficiency ratio of the rabbits. Rabbits fed 0%RTSSSM diets had highest average daily weight gain (ADWG) of 12.25g which was statistically similar to that of rabbits fed 10% RTSSSM diets (9.01g). Similarly, rabbits fed 0%RTSSSM diets had lower feed conversion ratio (0.73) and higher protein efficiency ratio (0.09) which were statistically similar to that of rabbits fed 10% RTSSSM diets (1.01) and (0.06) respectively. However, average daily feed intake was comparable among all the treatment groups. Higher cost/Kg feed (N/Kg) was recorded in rabbits fed 0%RTSSSM compared to other treatments.

Nutrients Digestibility of Rabbits fed 26-28°C Soaked Sorrel Seed Meals (RTSSSM)

Nutrient digestibility of rabbits fed replacement levels of (26-28°C) soaked sorrel seed meal (RTSSSM) is presented in Table 3. Significant differences ($p<0.05$) were observed in the digestibility of all nutrients analysed. Higher dry matter digestibility was recorded for rabbits fed 0%RTSSSM (91.04) and 10% RTSSSM (91.03) diets, which statistically similar to those fed on 20,30 and 40% RTSSSM diets. Similarly, higher crude protein digestibility was recorded for rabbits fed 0%RTSSSM and 10%RTSSS. However, rabbits fed 40% RTSSSM had the lowest value (40.92%) ($P<0.05$) CP digestibility, a similar trend was observed in crude fibre digestibility,(43.28%). Rabbits fed on 0% and 40% RTSSSM had lower fats digestibility (52.48 and 52.87%), respectively compared to other treatment groups.

Table 2: Growth performance of growing rabbits fed (26-28°C) soaked sorrel seed meal (RTSSSM)

Parameters	**RTSSSM (0%)**	**RTSSSM (10%)**	**RTSSSM (20%)**	**RTSSSM (30%)**	**RTSSSM (40%)**	**SEM**
IBW (g)	610.10	639.37	663.30	645.60	615.93	6.13
FBW (g)	1467.43^{a}	1270.27^{b}	1187.97^{b}	1248.30^{b}	1009.20^{c}	13.83

ADFI(g)	8.72	9.13	9.48	9.22	8.80	0.09
ADWG(g)	12.25[a]	9.01[a]	7.50[b]	8.61[b]	5.62[c]	0.19
FCR	0.73[d]	1.01[c]	1.27[b]	1.07[bc]	1.57[a]	0.09
PER	0.09[a]	0.06[ab]	0.05[ab]	0.06[ab]	0 .04[b]	0.00
Cost/kg feed (₦/Kg)	216.83[a]	212.38[b]	208.38[c]	204.39[d]	200.39[d]	0.00
Total feed cost (₦)	2133.60[a]	1766.70[ab]	1451.70[b]	1673.30[b]	1392.70 [b]	18.92
Cost/kg gain (₦/Kg)	1451.43[a]	1391.10[ab]	1219.92[b]	1360.41[b]	1378.91[b]	18.92

[abc] *Means in the same row with different superscripts differ (p<0.05); SEM: Standard Error of Meal PER: protein efficiency ratio; FCR: feed conversion ratio; ADWG: average weight gain; FBW: final body weight; IBW: initial body weight; SSM: soaked sorrel seed SEM: Standard Error of Mean*

Table 3: Nutrients digestibility by growing rabbits fed (26-28°C) Soaked Sorrel Seed Meals (RTSSSM)

Parameters (%)	**RTSSSM (0%)**	**RTSSSM (10%)**	**RTSSSM (20%)**	**RTSSSM (30%)**	**RTSSSM (40%)**	**SEM**
CP	57.27[a]	56.40[ab]	54.07[b]	43.54[c]	40.92[d]	0.11
Ash	52.30[a]	50.08[b]	46.00[c]	50.12[b]	47.83[c]	0.23
Fat	52.48[c]	66.07[a]	65.08[a]	57.25[b]	52.87[c]	0.13
CF	58.72[a]	54.18[b]	50.44[c]	45.43[d]	43.28[e]	0.08
DM	91.04[a]	91.03[a]	66.35[b]	66.12[b]	65.63[c]	0.04

NDF	33.27[a]	33.27[a]	32.17[b]	30.88[c]	32.63[ab]	0.02
ADF	30.72[a]	30.60[a]	29.56[a]	30.24[a]	25.29[b]	0.05
ADL	27.60[c]	33.08[a]	33.38[a]	31.07[ab]	29.64[bc]	0.11

[abcde] *Means in the same row with different superscripts differ (P<0.05); SEM: Standard Error of Meal ADL: acid detergent lignin; ADF: acid detergent fibre; NDF: neutral detergent fibre; DM: dry matter; CF: crude fibre; CP: crude protein; SSM: soaked sorrel seed*

Discussion

Growth Performance and cost benefit analysis of Growing Rabbits fed (26-28°C) Soaked Sorrel Seed Meals

Average daily gain (ADG) showed significant variation ranging from 8.61 to 12.25 g in this present work. Despite a lower ADFI, rabbits fed the control diet exhibited the highest ADG, a result comparable to those fed the 10% soaked sorrel seed meal (SSSM) diet. This suggests that the nutritional efficiency of the feed was superior at lower inclusion levels of SSSM. The observed decline in performance with higher SSSM inclusion may be attributed to residual anti-nutritional factors, such as alkaloids, which can interfere with nutrient absorption. The ADG values in this study was consistent with the range of 10.65 to 12.09 g reported by Olaoye *et al*. (2023) for rabbits fed processed sorrel seed meal. The trends for FCR) and PER followed a similar pattern, reinforcing the superior utilisation of diets with lower SSSM inclusion.

An economic analysis demonstrated that the cost per kilogram of feed decreased linearly with increasing levels of SSSM, ranging from ₦216.83 to ₦200.39. However, these feed costs were higher than those reported in previous studies utilising different processing methods for sorrel seed Igwebuike, 2001;Olaoye *et al*., 2023. Consequently, the feed cost per kilogram of gain in this study (₦1219.92 to ₦1451.43) was also higher. The total feed cost was lowest (₦1392.70) at the 40% SSSM inclusion level. Despite the higher overall feed cost, the cost per kilogram of gain for the 10% SSSM diet was similar to the control, due to the comparable total weight gain achieved by these two groups. This finding aligns with Olaoye *et al*. (2023) and indicates that replacing 10% of full-fat soya with (26-28°C)-soaked sorrel seed meal did not adversely affect economic performance, making it a viable and cost-comparable feeding strategy.

Nutrients Digestibility by Growing Rabbits fed (26-28°C) Soaked Sorrel Seed Meals

The assessment of apparent nutrient digestibility is a fundamental method for evaluating the bioavailability of dietary components in livestock (Bengaly *et al*., 2007). In the present study, the dry matter digestibility of the diet containing 10% (26-28°C) soaked sorrel seed meal (SSM) was comparable to the control, suggesting a similar rate of nutrient assimilation. Variations in dry matter digestibility among feed ingredients are well-documented and are influenced by their intrinsic physicochemical properties.

Crude protein digestibility was highest in rabbits fed the 10% SSM diet, mirroring the control group. This optimal inclusion level may have provided a favourable balance of fermentable substrates for caecal microorganisms, enhancing microbial protein synthesis and thereby improving the pool of digestible protein available to the host. The digestibility of ash, an indicator of mineral bioavailability, varied in accordance with the dietary mineral composition. Furthermore, fat digestibility was notably higher in the 10 and 30% SSM treatments, indicating that these formulations were particularly effective in promoting lipid utilisation, potentially through enhanced microbial activity in the cecum (Fielding,1991).

A key finding was the relationship between SSM inclusion and fibre utilisation. Crude fibre digestibility was highest at the 10% replacement level and was similar to the control, with a progressive decline as SSM inclusion increased. This aligns with the principle that the extent of caecal fibre degradation in rabbits is directly influenced by the dietary crude fibre content and its structure (Aderolu *et al*., 2007). The fibre fractions of the SSM, characterised by moderate Neutral Detergent Fibre (NDF) values, suggest a composition conducive to good digestibility. Feeds with low to moderate NDF concentrations (For example;25-35%) are typically highly digestible and can stimulate beneficial intestinal motility (Van Soest, 1994; Bakshi and Wadhwa, 2004). The overall fibre profile of the SSM indicates its suitability as a fibre source for rabbits, though it is important to note that agronomic factors such as climate, harvest time, and variety can influence the seeds' final nutritional composition (Taiwo *et al*., 2015).

Conclusion

The study demonstrated that room-temperature soaked sorrel seed meal (RTSSM) can be used as a partial replacement for full-fat soybean in diets of weanling rabbits without adversely affecting

feed intake. However, increasing RTSSM inclusion beyond 10% resulted in progressive reductions in growth performance, feed efficiency, protein utilisation, and the digestibility of some nutrients. The 10% RTSSM diet produced growth performance and nutrient utilisation comparable to the control diet while reducing feed cost, indicating that it is a suitable and economically viable inclusion level for weanling rabbits. It is therefore recommended that up to 10% room-temperature soaked sorrel seed meal be used as a partial replacement for full-fat soybean in weanling rabbit diets, particularly where reducing dependence on conventional protein sources and feed cost is a priority. Further research should evaluate different soaking durations and temperatures, as well as other processing methods, to determine their effectiveness in reducing anti-nutritional factors and improving nutrient utilisation. Studies involving larger populations, longer feeding periods, different rabbit breeds, and carcass characteristics, health indices, and reproductive performance are also recommended to establish the broader nutritional and economic potential of soaked sorrel seed meal in rabbit production.

Acknowledgement

We appreciate the staff of the Teaching and Research Farm of the University of Ibadan for allowing us use of research facilities.

Statement of Animal Rights

All husbandry and management practices were conducted in accordance with standard laboratory protocols by the Animal Care and Use Research Ethics Committee (ACUREC) (2021)

Conflict of Interest Statement

There are no conflicts of interest

Data Availability Statement

Data is available within the manuscript file.

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