https://dx.doi.org/10.4314/dujopas.v10i1b.3
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 10 No. 1b March 2024*

Performance and Cost Benefit of Organic Acid Supplementation in Broiler Diets Containing Graded Levels of Soaked *Balanite Aegyptiaca* Fruit Meal

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Abstract

Balanite aegyptiaca fruit meal (BAFM) is an alternative feed source that requires processing and supplementation with additives to enhance its utilization in broiler diets. A total of one hundred and twenty (120) day old broiler chickens were used for the study. They were allotted to four experimental treatments each replicated thrice with ten (10) chickens per replicate in a completely randomized design. Raw BAFM fruit was processed by soaking for 24 hours, dried and incorporated in the diets at 0.00, 2.50, 5.00 and 7.50% in T_1, T_2, T_3 and T_4 respectively. Acidifier (Fysal®) was supplemented in the diets of T_2-T_4 at 0.1%. The study monitored the following parameters; initial weight, final weight, weight gain, feed efficiency, and mortality rate. Cost benefit was also determined at the end of the study. Results obtained indicate that growth performance was poorer in chickens fed the control diet compared to others. Starter-phase chicks fed diets with the highest BAFM dietary inclusion level (7.5%) exhibited enhanced weight gain, improved feed conversion efficiency, and reduced feed cost per unit weight gain, while the pooled performance showed that the parameters declined at 7.5%. Cost benefit showed that feed cost per kilogram gain reduced up to 5% inclusion level of BAFM in the diets while it slightly increased at 7.5%, though better than the control group. At 5% dietary inclusion of BAFM with acidifier supplementation, feed cost per kilogram gain reduced by ₦95.22 (18.49%). Based on the results obtained in this study, it was concluded that soaked BAFM and acidifiers are good supplements that can be utilized in broiler diets at 5.0% and 0.1% respectively.

Keywords: Phytate; Acidifier; Broilers; Supplementation; *Balanite aegyptiaca*

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INTRODUCTION

Poultry production in Nigeria faces a significant challenge due to the soaring costs of feeding, constituting over 60% of the total production expenses (Sogbesan *et al*., 2005). This highlights the need for cost-effective alternatives in poultry nutrition, prompting research into unconventional feedstuffs that pose minimal competition with human utilization (Ojewola and Udom, 2005).

Balanite aegyptiaca, commonly known as "Aduwa" in the Hausa language, has emerged as a promising alternative feed source. The nutrient composition of its fruit includes crude protein (35.26%), crude fat (48.82%), ash (3.35%), and nitrogen-free extract (2.50%) (Samuel *et al*., 1997). he presence of anti-nutritional factors, such as tannins, oxalate, phytic acid, and saponins have also been reported (Chothani and Vaghasiya, 2011).

Despite the rich nutrient profile of *Balanite aegyptiaca* fruit (BAFM), animal nutritionists have yet to extensively explore its potential in poultry diets. Idachaba *et al*. (2017) emphasize the importance of identifying suitable processing methods for alternative feedstuffs, with the supplementation of feed additives standing out as a potential avenue for enhancing utilization. Acidifiers, in particular, have been recognized for their ability to mitigate the negative effects of anti-nutritional factors in vegetative feedstuffs (Idachaba *et al*., 2019).
Existing studies (Boling *et al*., 2000; Liem *et al*., 2007; Idachaba *et al*., 2017, Idachaba *et al*., 2019) underscore the potential benefits of incorporating acidifiers into broiler diets containing alternative feedstuffs. However, a critical gap remains in the literature regarding the use of acidifiers in diets containing *Balanite aegyptiaca* fruits for broiler chickens.

This study aims to address this gap and add valuable insights to the existing body of knowledge by evaluating the performance and economic implications of supplementing organic acids in broiler diets containing graded levels of processed BAFM.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, Federal College of Forestry, Jos-Plateau State. The farm is located on latitude 9^0 56'49.0" N and longitude 8^0 53'34.1" E, at an altitude of 1250 m above sea level. The temperature of the area ranges between 21 and 25^{o}C depending on the season. The wet period in Jos is between April and November with annual rainfall between 1200 and 1500 mm [Federal College of Forestry (FCF), 2019].

Source of Ingredients and Broiler Chicks

Balanites aegyptiaca fruits were obtained from Yandoya market located in Jos metropolis, Plateau State, Nigeria. Organic acid (FYSAL®) was sourced from a feed mill in Zaria, Kaduna State, Nigeria. FYSAL® contains a blend of acidifiers viz; sorbic, lactic, propionic, ascorbic and citric acids.

One hundred and twenty (120) broiler chicks of Cobb-500 strain were sourced from Zartech hatchery located in Ibadan, Oyo State, Southwestern Nigeria

Processing of *Balanites aegyptiaca* Fruits (Soaking)

Raw *Balanites aegyptiaca* fruits were soaked in four litres of water in a plastic container for a duration of 24 hours. The water was allowed to drain out and fresh water replaced after every

eight hours of soaking duration. At the end the 24-hour soaking duration, the samples were properly dried and taken to the Biochemistry Laboratory of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University (ABU) Zaria, Kaduna State. The values of proximate composition and anti-nutritional factors in BAFM from our previous study (Abdullahi *et al.,* 2018) were used to formulate the experimental diets.

Experimental Design and Management of Chickens

The study employed a completely randomized design (CRD) consisting of one hundred and twenty (120), day-old Cobb-500 broiler chicks. The chicks were randomly assigned to 12 groups (4 dietary treatments x 3 replicates) with 10 birds per replicate. The chickens were reared in a deep litter system with unrestricted access to feed and water. Standard management practices appropriate for broilers were rigorously implemented throughout the experiment (Sonaiya and Swan, 2004). Parameters studied include initial weight, final weight, weight gain, and feed intake. Additionally, calculations were conducted for feed conversion ratio and feed cost per kilogram gain, while occurrences of mortality were documented in real-time.

Experimental Diets

Four diets were developed at starter and finisher phases each containing 0.00, 2.50, 5.00 and 7.50% inclusion levels of soaked *Balanites aegyptiaca* fruit meal (BAFM) in treatments T_1, T_2, T_3 and T_4 respectively. Supplementation of the organic acid (FYSAL®) was done following the manufacturers' recommendation of 0.1% in diets two to four. Tables 1 and 2 outline the compositions of the experimental diets for both the starter and finisher phases.

Table 1: Ingredients composition of broiler starter diets containing soaked *Balanite aegyptiaca* fruit meal with acidifier supplementation

Ingredients	Inclusion Levels of BAFM (%)			
	0.00	**2.50**	**5.00**	**7.50**
Maize	57.00	55.00	52.80	51.00
GNC	19.00	16.50	14.00	11.50
Soya cake	17.55	17.55	17.55	17.55
Bone meal	2.90	2.90	2.90	2.90
Balanite aegyptiaca	-	2.50	5.00	7.50
Limestone	1.10	1.10	1.10	1.10
Maize offal	1.00	2.10	3.50	4.40
Blood meal	0.70	1.60	2.40	3.30
Salt	0.30	0.30	0.30	0.30
*Vitamin Premix	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10
FYSAL®	-	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00
Calculated Analyses				
Crude protein (%)	22.17	22.14	22.09	22.03
ME (Kcal/Kg)	2890	2894	2899	2908
Ether extract (%)	4.52	4.55	4.65	4.70
Crude fibre (%)	3.96	4.02	4.12	4.17
Calcium (%)	1.23	1.23	1.23	1.23
Available Phosphorus (%)	0.50	0.50	0.50	0.50
Lysine (%)	1.16	1.18	1.19	1.21
Methionine (%)	0.77	0.77	0.76	0.75
Cost per kg diet	107.03	106.27	105.39	104.69

GNC = groundnut cake, Kcal= kilo calorie, Kg= kilogram. BAFM= *Balanite aegyptiaca* fruit meal.

*The Biomix chick premix was formulated to provide, per kilogram of diet, the following concentrations of essential nutrients: vitamin A at 10,000 International Units (IU); vitamin D3 at 2,000 I.U; vitamin E at 23 milligrams; vitamin K at 2 milligrams; calcium pantothenate at 7.5 milligrams; vitamin B12 at 0.015 milligrams; folic acid at 0.75 milligrams; choline chloride at 300 milligrams; vitamin B1 at 1.8 milligrams; vitamin B2 at 5 milligrams; vitamin B6 at 3 milligrams; manganese at 40 milligrams; iron at 20 milligrams; zinc at 53.34 milligrams; copper at 3 milligrams; iodine at 1 milligram; cobalt at 0.2 milligrams; selenium at 0.2 milligrams; and additional zinc at 30 milligrams.

Table 2: Ingredients composition of broiler finisher diets containing levels of soaked *Balanite aegyptiaca* fruit meal with acidifier supplementation

	Inclusion Levels of BAFM (%)			
Ingredients	**0.00**	**2.50**	**5.007.50**	
Maize	68.70	67.00	64.70	61.35
Soya cake	17.50	17.50	17.50	17.50
GNC	5.30	4.20	3.80	1.00
Blood meal	3.50	3.60	3.40	4.40
Bone meal	2.90	2.95	2.95	2.95
Limestone	1.10	1.10	1.10	1.10
Balanites aegyptiaca	0.00	2.50	5.00	7.50
Salt	0.30	0.30	0.30	0.30
*Vitamin Premix	0.25	0.25	0.25	0.25
Lysine	0.20	0.20	0.20	0.20
Methionine	0.20	0.20	0.20	0.20
Maize offal	0.05	0.20	0.60	3.25
FYSAL®	-	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Crude protein (%)	19.89	19.65	19.53	19.45
ME (Kcal/Kg)	3005	3018	3026	3030
Ether extract (%)	4.10	4.19	4.30	4.36
Crude fibre (%)	3.29	3.35	3.46	3.65
Calcium (%)	1.21	1.22	1.22	1.22
Available Phosphorus (%)	0.50	0.50	0.50	0.50
Lysine (%)	1.18	1.18	1.19	1.20
Methionine (%)	0.77	0.76	0.74	0.73
Cost per kg diet (₦)	112.43	111.61	110.99	108.86

GNC = groundnut cake, Kcal= kilo calorie, Kg= kilogram. BAFM= *Balanite aegyptiaca* fruit meal.

*The Biomix chick premix was formulated to provide, per kilogram of diet, the following concentrations of essential nutrients: vitamin A at 10,000 International Units (IU); vitamin D3 at 2,000 I.U; vitamin E at 23 milligrams; vitamin K at 2 milligrams; calcium pantothenate at 7.5 milligrams; vitamin B12 at 0.015 milligrams; folic acid at 0.75 milligrams; choline chloride at 300 milligrams; vitamin B1 at 1.8 milligrams; vitamin B2 at 5 milligrams; vitamin B6 at 3 milligrams; manganese at 40 milligrams; iron at 20 milligrams; zinc at 53.34 milligrams; copper at 3 milligrams; iodine at 1 milligram; cobalt at 0.2 milligrams; selenium at 0.2 milligrams; and additional zinc at 30 milligrams.

Laboratory Analyses

Samples of raw and processed BAFM were analysed at the Biochemistry Laboratory, Department of Animal Science, ABU, Zaria, for proximate compositions according to

procedures of Association of Official Analytical Chemists (AOAC) (2005) and anti-nutritional factors according to the method reported by Cooke and Maduagwu (1978).

Data Analyses

The experimental data was analyzed using the general linear model procedure of SAS (2001) to perform analysis of variance. Furthermore, Duncan's Multiple Range Test (Duncan, 1955) was employed to determine significant differences between the treatment means.

RESULTS

Performance of Broiler Starter Chickens Fed with Soaked BAFM-Based Diets and Organic Acid Supplementation (0-4weeks)

The performance at starter phase, of broiler chicks fed with diets containing varied levels of soaked *Balanite aegyptiaca* fruit meal is presented in Table 3. In comparison to chicks from other treatment groups, chicks that were fed diets based on 5.0 and 7.5% BAFM recorded a significantly higher final weight and weight gain (P<0.05). Following this were chicks fed 2.5% BAFM based diet while the control group showed the poorest result. There was significantly (P<0.05) higher feed intake among chicks fed 5.0 and 7.5% BAFM based diets followed by those fed 2.5% BAFM based diet, while the control group showed the least feed intake. Chicks fed 2.5, 5.0 and 7.5% BAFM based diets showed similar results in feed conversion ratio while those on the control diet showed significantly (P<0.05) poorer results. Feed cost per kg gain was highest in the control group, followed by the chicks fed 2.5 and 5.0% BAFM based diet. Chicks fed 7.5% BAFM diet showed the least value in feed cost per kg gain. Save for the first treatment (T1), mortality occurred in all treatments.

Table 3: Growth Performance of Broiler Chicks Fed with Soaked BAFM-Based Diets and Organic Acid Supplementation (0-4weeks)

		Levels of BAFM (%)			
Parameters	**Control**	**2.50**	**5.00**	**7.50**	**SEM**
Initial weight (g/bird)	44.44	44.45	44.45	44.44	0.01
Final weight (g/bird)	312.96^{c}	377.78^{b}	416.40^{a}	417.82^{a}	18.06
Weight gain (g/bird)	268.52^{c}	333.33^{b}	371.95^{a}	373.38^{a}	18.06
Feed intake (g/bird)	761.11^{b}	828.24^{ab}	926.49^{a}	892.59^{a}	53.41
Feed conversion ratio	2.85^{b}	2.48^{a}	2.50^{a}	2.41^{a}	0.17
Feed cost/kg gain (₦/kg)	305.02	263.55	263.45	252.30	0.00
Mortality (%)	0.00	3.70	11.11	3.70	0.00

a, b=Means bearing distinct superscripts within the same row are significantly different (P<0.05). SEM= Standard error of mean g/bird= gram per bird, %= Percentage, ₦/kg= Naira per kilogram, BAFM= *Balanite aegyptiaca* fruit meal

Pooled Performance of Chickens Fed with Soaked BAFM-Based Diets and Organic Acid Supplementation (0-8weeks)

Table 4 presents the pooled performance of chickens fed with soaked BAFM diets and acidifier supplementation. Weight gain was higher in chickens fed with 5.0% BAFM based diet followed by chickens fed with 7.5% BAFM, while others did not differ significantly (P>0.05). The daily feed intake of chickens receiving diets based on 2.5, 5.0%, and 7.5% BAFM was significantly (P<0.05) higher compared to the control group, which displayed the lowest intake. Chickens fed with 5.0% BAFM exhibited the most favorable feed conversion ratio, followed by those fed with 7.5% BAFM. Chickens fed with the control diet and diet containing 2.5% BAFM showed no significant (P<0.05) difference. Mortality was recorded in all treatment groups.

Table 4: Performance of Chickens Fed with Soaked BAFM-Based Diets and Organic Acid Supplementation (0-8 weeks)

Parameters	Control	Levels of BAFM (%)			SEM
		2.5	5.0	7.5	
Initial weight (g)	44.44	44.45	44.44	44.45	0.01
Final weight (g)	1341.27^{b}	1440.55^{b}	1703.33^{a}	1604.17^{ab}	110.68
Weight gain (g/b/d)	23.16^{b}	24.93^{b}	29.62^{a}	27.85^{ab}	1.97
Feed intake (g/b/d)	53.69^{b}	56.75^{a}	56.68^{a}	58.15^{a}	1.23
FCR	2.35^{c}	2.28^{c}	1.94^{a}	2.11^{b}	0.06
Mortality (%)	22.22	38.32	40.28	22.93	0.00

a, b=Means bearing distinct superscripts within the same row are significantly different (P<0.05), SEM= Standard error of mean g/bird= gram per bird, %= percentage, FCR= Feed conversion ratio, BAFM= *Balanite aegyptiaca* fruit meal

Cost Benefits of Raising Broiler Chickens on Soaked BAFM-based Diets and Acidifier Supplementation

Table 6 presents the cost benefit of utilizing BAFM in broiler diets and supplementation of acidifier. Total feed intake was highest among chickens fed with 7.5% BAFM based diet followed by those fed with 2.5 and 5.0% BAFM based diet. The lowest feed intake was recorded among chickens on the control diet. Feed cost was highest among chickens in the control group while it declined with increased inclusion of BAFM across the other treatments. Total feed cost was highest in all treatments with diets containing BAFM while it was least in the control group. Total weight gain was highest among chickens fed with 5.0% BAFM based diet followed by those fed with 7.5% BAFM based diet. Compared to the control group, weight gain was greater among birds fed with diet in which BAFM was included at 2.5%. Chickens in the control group had higher feed cost per kg gain above other groups and was followed by chickens fed with 2.5% BAFM based diet. This was followed also by chickens fed with 7.5% BAFM based diet while chickens fed with diets containing 5.0% BAFM had the least value.

Table 5: Cost Benefits of Raising Broiler Chickens on Soaked BAFM-based Diets and Acidifier Supplementation

Parameters	Control	Levels of BAFM (%)		
		2.5	5.0	7.5
Total Feed Intake (kg)	3.01	3.18	3.17	3.26
Feed Cost (₦/kg)	219.46	217.88	216.38	213.55
Total Feed Cost (₦/kg)	659.84	692.13	686.64	695.46
Total Weight gain (kg)	1.30	1.40	1.66	1.56
Feed cost/Gain (₦/kg)	515.00	497.49	419.78	451.30

SEM= Standard error of mean, BAFM= *Balanite aegyptiaca* fruit meal, kg= Kilogram, ₦= Naira, ₦/kg= Naira p kilogram

DISCUSSION

Growth Performance of Broiler Starter Chickens Fed with BAFM-Based Diets and Organic Acid Supplementation (0-4weeks)

Chickens on diets with inclusion of BAFM had greater final weight and weight gain compared to those fed with the control diet. The more balanced array of amino acids in *Balanite aegyptiaca* fruit compared to groundnut cake which it replaced in the diets, could be responsible for this. According to Mohammed *et al.* (2002), *Balanite aegyptiaca* fruit contains higher lysine (3.52g/100g protein) and methionine (1.34 g/100 g protein) compared to groundnut cake which contains lysine (0.46 g/100 g protein) and methionine (0.34 g/100 g protein). Organic acid supplementation in diets of chicks fed with *Balanite aegyptiaca* fruit meal may also be attributed to the improved weight gain compared to the control group. Idachaba *et al*. (2017) reported that organic acid supplementation in broiler diets improved weight gain and other productive parameters. The authors further reiterated that organic acids reduce the chelating effect of anti-nutrients in diets by displacing them in the lumen of the gut, thereby enhancing improved nutrient absorption.

The higher weight gain at 5.0 and 7.5% levels BAFM dietary inclusion could be indication that the chicks were able to utilize BAFM more efficiently at both levels. The supplementation of acidifier in the diets may have also helped to reduce the effect of the residual anti-nutrients in BAFM. Abdullahi (2019) observed increase in weight gain of broiler chicks on diets containing graded levels of soaked BAFM. The author reported that weight gain increased up to 20% level of BAFM inclusion in the diet.

The progressive inclusion of BAFM in the diets of the chicks resulted in enhanced feed intake and improved feed conversion ratio (FCR). This improvement may be attributed to the increased palatability and enhanced utilization of nutrient components within the diets. Improved feed palatability at inclusion levels 5.0 and 7.5% BAFM may have stimulated feed intake similar to the report of Shimelis and Raskshit (2007). Organic acid supplementation also improved feed consumption in chickens as reported by Moghadam *et al*. (2006); Youssef *et al*. (2013).

The reduction in feed cost per kilogram gain among chicks fed with graded levels of BAFM based diets showed that BAFM coupled with with the acidifier lowered cost of production while improving productive parameters (weight gain and FCR). Although no mortality was observed in chicks in the control group, post mortem examination did not indicate that mortality resulted from the experimental diets.

Pooled Performance of Broiler Starter Chickens Fed with BAFM-Based Diets and Organic Acid Supplementation (0-8weeks)

The pooled performance of chickens showed improved final weight across the levels of BAFM dietary inclusion, further supporting the report that BAFM has a good amino acid profile (Maneemagalai and Reena, 2011; Mohammed and Mohammed, 2018). These authors reported that BAFM contains a more balanced array of amino acids compared to groundnut cake in which it replaced in this study. The supplementation of organic acids in the diets may have also contributed to the improved performance according to the reports of Idachaba *et al*. (2017) and Idachaba *et al*. (2019).

Chickens fed with 5.0 and 7.5% BAFM based diets showed better final weight and daily weight gain compared to others which indicates better feed utilization at both levels. Incorporation of the bioacid combined with varying levels of BAFM, led to an increase in daily feed intake, indicating enhanced feed palatability. This could also explain the improved feed to gain ratio observed across the treatment groups. Chickens fed with 5.0% BAFM based diet had the highest percentage mortality; post mortem examinations however showed that dietary treatments were not the cause of increased mortality among the chickens.

Cost Benefit of Feeding Broiler Chickens with Soaked BAFM-based Diets and Acidifier Supplementation

Chickens fed with BAFM-based diets and acidifier supplementation exhibited higher total feed intake (kg), while the feed cost (₦) was lower in all treatments except the control group. This implies that processing (soaking) BAFM improved feed palatability such that total feed consumption increased while cost incurred on the feed/diets reduced. This observation aligns with the findings of Idachaba (2018), who reported improved feed palatability and cost reduction in chickens fed alternative feed ingredients with acidifier supplementation.. The rise in total weight gain also supports this observation and was in tandem with result of weight gain at starter and finisher phases of this study. The cost per kilogram gain in feed decreased with the inclusion of BAFM and acidifiers in the chickens' diets, consistent with the conclusions drawn by Mahfudz *et al*. (2020) regarding the economic advantages of supplementing broiler diets with acidifiers. During the study period, the market price of groundnut cake was ₦160, whereas the total cost incurred for *Balanite aegyptiaca* fruits, including processing, was ₦77. This shows that BAFM can reduce cost implication in broiler production. The best weight gain and final weight at finisher phase and in the pooled performance were observed among chickens fed with 5.0% BAFM based diet. Thus, BAFM inclusion in the diet at 5.0% with acidifier supplementation reduced cost of production by ₦95.22.

CONCLUSION

The incorporation of 7.5% BAFM and acidifier supplementation led to a substantial 39.05% improvement in weight gain and a reduction of ₦52.72 in feed cost per kilogram gain during the starter phase. During the (0-8 weeks) period, the inclusion of 5.0% BAFM led to a notable 21.26% improvement in weight gain and a decrease in feed cost per kilogram gain by ₦95.22. Owing to the results obtained in this study, it was concluded that BAFM, processed through soaking to mitigate anti-nutrient content, can be included in broiler diets at 5.0% with the addition of 0.1% organic acid supplementation.

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