Discovery Agriculture

Starter Phase Growth Performance and Economic Benefits of Urea-Treated Fermented Orange Peel Meal in Broiler Chicken Diets at Varying Fermentation Periods

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To Cite:
Mojeed AO, Sunday OT, Moji A, Shehu NS, Iliyasu AH. Starter Phase Growth Performance and Economic Benefits of Urea-Treated Fermented Orange Peel Meal in Broiler Chicken Diets at Varying Fermentation Periods. *Discovery Agriculture* 2026; 12: e2da3177
doi:

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Peer-Review History
Received: 25 March 2025
Reviewed & Revised: 16/April/2025 to 12/January/2026
Accepted: 21 January 2026
Published: 03 February 2026

Peer-Review Model
External peer-review was done through double-blind method.

Discovery Agriculture
pISSN 2347-3819; eISSN 2347-386X

ABSTRACT

This study was conducted to evaluate starter phase growth performance and economic benefit of broiler chickens fed diets containing 20% fermented urea-treated orange peel meal (FUTOPM) fermented for 3, 6 and 9 days using *Aspergillus niger*. Orange peels were treated with urea, fungal cultures were added, and anaerobic fermentation was carried out. A total of 240-day-old broiler chicks were used in the study. The completely randomized design was used. Parameters of growth performance like body weight, weight gain, and cost aspects were measured. Statistical analysis was done using the General Linear Model procedure of SAS. Duncan's Multiple Range Test was used at a significance level of 5% to compare the means of the treatments. The result showed that the highest final body weight (953.33g) and total weight gain (911.91g) were recorded in the group fed the 9-day FUTOPM. This was followed by the group fermented for 6 days. The cost of feeding per kilogram of the group fermented for 9 days was the lowest (₦665.90). However, the cost-benefit ratio was highest in the group fermented for 6 days (1.32). therefore, it was concluded that the longer the fermentation duration of urea-treated fermented orange peels, the better the early growth performance and the lower the production costs. Consequently, it was recommended that fermented urea-treated orange peels fermented for a period of 9 days be included in the diets of growing chickens.

Keywords: Fermentation, Starter, Performance, Economics, Urea

1. INTRODUCTION

The starter stage in the production of broilers takes a critical role in determining the pattern of growth, the development of the immune system, and survivability, which has significant implications for market performance (Idrissa *et al*., 2025). The diets designed for the starter stage are highly dependent on protein and energy, hence the reason starter diets are the most expensive component of the overall diets of broilers (Adegbenro *et al*., 2017). There are significant economic benefits for the poultry

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industry in minimizing the cost of starter diets without compromising the early growth rate (Afolabi *et al*., 2023).

Urea-supplemented orange peel meal, which underwent fermentation with *Aspergillus niger*, has lately gained popularity as an effective supplement in animal feed, mainly because of the increment in the crude protein levels and the decrement in the fibre content (Haque *et al*., 2021). Longer fermentation times can lead to increased enzyme production, which in turn can be beneficial for the proper degradation and utilization of nutrients in the form that is more ideal for the underdeveloped digestive system of chicks (Ricci *et al*., 2023). Increased nutrient utilization in the early stage of life has been reported to improve the growth performance in the starter stage (Mohamed *et al*., 2023).

The nutritional interventions that take place early in life could have long-term effects on the subsequent phases of growth due to their ability to modulate metabolic programming as well as the development of the gut (West, 2023). Appropriate optimization of fermentation could thus be useful for enhanced early growth as well as reduced mortality, thereby improving overall performance (Idrissa *et al*., 2025). Prolongation of fermentation could, on the other hand, negatively modulate the substrate composition, thereby decreasing its value for the young chicks (Singh *et al*., 2021).

Economic analysis of starter diets usually focuses on feed cost per unit of weight gain and benefit-cost ratio, which are highly sensitive to ingredient costs and processing needs (Adegbenro *et al*., 2017). The need for finding an optimal fermentation time that is economically optimal and biologically effective still remains important. The present experiment was therefore carried out to evaluate growth performance and economic efficiency of broiler starters on urea-treated fermented orange peel meal at different fermentation periods.

2. MATERIALS AND METHODS

Study Area

The feeding experiment was carried out at the Poultry Unit, Department of Animal Science Teaching and Research Farm, Ahmadu Bello University (ABU), Zaria, Nigeria. The farm lies at 11°17''N latitude and 07°64''E longitude, with an estimated height of 671 meters above sea level (Google Map, 2024). The area has clear wet and dry seasons with mean annual rainfall varying from 700mm to 1,400mm per year. The wet season usually begins from the last week of April or early May, peaks from July to August, and ends by mid-October. This period is followed by the harmattan phase with cool and dry air mass. The average daily temperature varies from 15.6°C in the cool season to 38.5°C in the hot season (IARMS, 2024). Relative humidity also varies from 36% in the dry season to 78.5% in the wet season (IARMS, 2024).

Collection and Processing of Orange (*Citrus sinensis*) Peel

Orange peels (Citrus sinensis) of different varieties were sourced from vendors widely known as Mai-lemu in the markets of Samaru, Sabo, and Randa Kano, located in the city of Zaria, Kaduna State. The peels were washed with clean tap water to eliminate dirt, debris, and pesticide residues. Drying was done under direct solar exposure with temperatures of 28-30°C for three days, when the moisture content was below 12%. The dried peels were ground into fine powder using a hammer mill (Model 912, Winona Attrition Mill Co., USA) fitted with a 2.36 mm (14-mesh) screen.

Fermentation of Orange Peels Using *Aspergillus niger*

Enrichment and Isolation of *Aspergillus niger*

Isolation and enrichment of *A. niger* were done at the Microbiology Laboratory, Faculty of Life Sciences, Ahmadu Bello University, Zaria. Spoiled orange fruits were used as the source of the cellulolytic fungus. Tissue portions about 3 to 5 cm long were aseptically excised using a scalpel and cultured on potato dextrose agar containing 500 mg/mL streptomycin. Plates were incubated at room temperature for seven days. Pure cultures were transferred to PDA slants and stored at 4°C. Identification of the isolated fungus was based on microscopic features outlined by Diba *et al*. (2007). The isolate was also tested for aflatoxin production using ultraviolet light.

Preparation of Inoculum

The inoculum was prepared by aseptically transferring a loopful of fungal mycelia to an inoculum medium that contained 1% sucrose and 0.2% yeast extract, pH 5.50. Culture flasks were aerobically incubated at room temperature using a rotary shaker for a period of 24 to 48 hours. A spore suspension was prepared and adjusted to a final concentration of 2.0×10^6 spores/mL. Spore counts were estimated using a haemocytometer (Neubauer-ruled Bright Line counting chamber; Hausser Scientific, Horsham, PA) as described by Wolk *et al*. (2000).

Fermentation Procedure

One hundred grams of dried and finely ground OPM was packed in aluminium foil and sterilized by autoclaving. One gram of urea was dissolved in 100 mL of sterile water and used to moisten the sterilized OPM to be treated with urea. Both the urea-treated and the untreated OPM were inoculated with 10 mL of the prepared *A. niger* starter culture. The substrates were packed in cellophane-covered containers and allowed to ferment anaerobically as described by Aro *et al*. (2010) and Laconi and Jayanegara (2015). The fermentation was stopped after the third, sixth, and ninth days, respectively. The fermented substrates underwent sun drying for two days with temperatures of 28 to 30°C to inactivate the microbial activity. The dried substrates were packed in airtight plastic containers before the proximate and amino acid composition analyses.

Pre-experimental Operations

Before the introduction of the experimental birds, the poultry pens were thoroughly cleaned, washed, and disinfected. The fumigation of the poultry pens and the surrounding environment was done using 40% formaldehyde. The poultry pens were divided into experimental units and were uniquely labelled.

Ethical Clearance

The use of the experimental animals was approved by the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC) before the commencement of this study. All the procedures were done based on guidelines on animal welfare with approval number ABUCAUC/2023/147.

Dietary Treatments

Experimental diets were formulated to meet the nutritional needs of the broiler chicks based on the recommendation of the National Research Council (NRC, 2000). Fermented urea-treated orange peel meal (FUTOPM) was added at 20% incorporation into the experimental diets. The composition of the starter diets was altered to make the diets isonitrogenous and isocaloric, as presented in Table 1.

Table 1: Ingredients composition and proximate composition of broiler starter diets containing fermented urea treated orange peel meal ((0-4 weeks)

INGREDIENTS	FERMENTATION DURATION			
	TOTAL = (20%)			
	Control	**3 days**	**6 days**	**9 days**
Maize	56.80	39.40	38.20	37.50
Soybean meal	29.00	29.00	29.00	29.00
Groundnut cake	10.00	7.00	8.60	9.30
FUTOPM	0.00	20.00	20.00	20.00
Lysine	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20
Bone Meal	3.00	3.00	3.00	3.00
Limestone	0.40	0.40	0.40	0.40
Vit/Min Premix[1]	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**

Calculated Analysis	2963.21	2947.73	2993.45	2957.28
ME (Kcal/kg) DM	23.00	23.00	23.00	23.00
Crude Protein (%)	3.23	3.23	3.23	3.23
Ether Extract (%)	3.52	3.60	3.62	3.63
Crude Fibre (%)	1.31	1.31	1.31	1.31
Calcium (%)	0.87	0.87	0.87	0.87
Phosphorus (%)	1.26	1.26	1.26	1.26
Lysine (%)	0.55	0.55	0.55	0.55
Met. + Cys. (%)	772.79	755.24	737.79	730.58
Cost (₦/kg)				
Proximate Composition				
Dry Matter (%)	90.66	89.62	87.29	88.61
Crude Protein (%)	21.71	21.53	22.82	23.37
Ash (%)	7.90	10.42	9.04	12.04
Crude Fibre (%)	5.73	5.30	4.36	5.79
Ether Extract (%)	7.58	8.06	7.33	5.54
Nitrogen Free Extract	76.27	68.33	75.86	81.58

FUTOPM: Fermented Urea Treated Orange Peel Meal, ME: Metabolizable Energy, Met: Methionine, Cys: Cysteine, [1]Vitamin/Mineral Premix (Bio-mix®) Each 2.5kg supplied: Vit A 10,000,000 iu; Vit D_3 2,000,000 iu; Vit E 23,000mg; Vit K_3 2,000mg; Vit B_1 1,800mg; Vit B_2 5,500mg; Niacin 27,500mg; Pantothenic acid 7,500mg; Vit B_6 3,000mg; Vit B_{12} 15mg; Folic acid 750mg; Biotin 60mg; Choline Chloride 300, 000mg; Cobalt 200mg, Copper 3,000mg; Iodine 1,000mg; Iron 20, 000mg; Manganese 40,000mg; Selenium 200mg; Zinc 30,000mg, Antioxidant 1,250mg.

Experimental Design and Management of Birds

A total of 240-day-old Arbor Acre broiler chicks of mixed sex were obtained from Dahmas Hatchery, Ibadan, Oyo State, Nigeria. The chicks were randomly assigned to four treatment diets containing 20% fermented urea-treated orange peel meal (FUTOPM): the control diet, diets fermented for 3 days, 6 days, and 9 days. Each treatment was allocated four replicates, with 15 chicks per replicate. The body weights of the chicks were standardized (± 1g) using a 10kg Camry digital scale (4th generation, Taiwan) before the commencement of the experiment, and the chicks were provided with their respective diets and clean water for the 28-day starter period.

The birds were kept in deep litter pens at the Department of Animal Science Teaching and Research Farm, Ahmadu Bello University, Zaria. All the birds were electrically brooded. Normal husbandry routines were followed throughout the experiment. The starter diets were designed to be isonitrogenous, containing 23% crude protein, and isocaloric, providing about 2,900 kcal/kg metabolizable energy, as shown in Table 1. Vaccinations were given according to the standard broiler vaccination program.

The design adopted was Completely Randomised Design (CRD). The daily feed allowance was measured, and the residues were collected and weighed every week to measure the feed intake. Weights were also taken every week, allowing the calculation of the feed conversion ratio over the 28-day period. Mortality rate was recorded daily and presented as a percentage per treatment every day. Live weights, daily weight gains, and average daily feed intake per treatment were calculated.

Cost Analysis

The economic evaluation of the dietary treatments was conducted using cost-benefit analysis techniques as outlined by Akanbi (2019). The analysis was based on the current market costs evident throughout the experimental period, which ranged from September 2024 to February 2025. The cost-benefit analysis evaluated the cost implications of the feeds with respect to the use of fermented orange peel meal. The orange peel meal was assigned costs based on the costs associated with its collection, handling, labor, and processing. The costs associated with vaccines, drugs, litter, and other management costs remained the same for all the treatments. The cost-benefit ratio was used as an economic measure of the viability of using orange peel meal in the production of broiler chicken feeds.

$$Cost\ Benefit\ Ratio = \frac{Total\ Revenue}{Total\ variable\ Cost}$$

Where the value obtained is < 1 shows there is no benefit in using FUTOPM in the diets of broiler chickens and where the value is >1, shows there is benefits in using FUTOPM in the diets of broiler chickens.

Data Analysis

All data that were collected were subjected to General Linear Model (GLM) procedure of SAS (2008, version 9.2). Significant treatment means were compared using Duncan's Multiple Range Test (1955) of the same package. Significance was accepted at 5% level of probability.

3. RESULTS & DISCUSSION

The growth performance of broiler chickens fed diet containing 20% inclusion of Fermented Urea-Treated Orange Peel Meal (FUTOPM) for different fermentation times (0-4 weeks) in the starter phase is shown in Table 2. Final body weight was significantly different ($P < 0.05$). The 9-day FUTOPM-fed broiler chickens showed the maximum final body weight (953.33 g/bird), significantly higher than the control (884.88 g/bird) and 3-day FUTOPM-fed (882.38 g/bird) broiler chickens. The 6-day FUTOPM-fed broiler chickens showed a final body weight of 935.00 g/bird, which was not significantly different from the 9-day fermentation treatment.

A similar trend was found regarding weight gain. The highest weight gain of 911.91 g/bird was found in the 9-day FUTOPM treatment, which was significantly higher compared to that of the control (843.45 g/bird) and 3-day FUTOPM (840.95 g/bird) groups. However, weight gain of 893.58 g/bird was found to be statistically similar to that of the 9-day FUTOPM treatment in the 6-day FUTOPM treatment. This could be due to increased crude protein levels because of microbial fermentation. This result is supported by Alshelmani *et al*. (2016), who found that growth performance of broiler chickens was enhanced by feeding fermented palm kernel cake.

Total feed consumption was also influenced by the dietary groups ($P < 0.05$). Birds in the 6-day FUTOPM groups fed less (1062.80 g/bird) than the control (1172.91 g/bird) and 3-day FUTOPM groups (1153.86 g/bird). However, the 9-day FUTOPM groups (1109.19 g/bird) were not significantly different from the 6-day groups. Daily feed consumption was also similar, with the lowest being in the 6-day FUTOPM groups (37.96 g/bird). The control and 3-day FUTOPM groups fed significantly more, but the 9-day groups (39.61 g/bird) were statistically similar to the 6-day groups.

The feed conversion ratio (FCR) had a notable improvement with an increased fermentation period ($P < 0.05$). The birds that were fed the 6-day and 9-day FUTOPM had better FCR performance with ratios of 1.19 and 1.22, respectively, than the control and the 3-day FUTOPM, with ratios of 1.39 and 1.38. The results indicated that fermentation increased the digestibility and utilization of nutrients, hence improving feed conversion efficiency. Similar improvements in feed conversion ratios were observed by See *et al*. (2024), who found that fermented orange peel diets increased feed efficiency in broiler chickens. The cost of feed per kilogram of weight gained was numerically lower in the birds that were fed the 6-day and 9-day FUTOPM diets than in the control and the 3-day FUTOPM diets. The initial weight and mortality rates were not significantly different ($P > 0.05$) among the treatment groups.

The economic implications of the use of diets with 20% FUTOPM at different fermentation times for broiler chickens are presented in Table 3. There was a reduction in the cost of the diet with the increase in the fermentation time, with the lowest cost of the 9-day FUTOPM diet at ₦730.58/kg, compared to the 6-day (₦737.79/kg) and 3-day (₦755.24/kg) FUTOPM diets and the control diet at ₦772.79/kg. Total feeding per bird was lowest in the 6-day FUTOPM group at 1.06 kg/bird, compared to the control group at 1.17 kg/bird.

The final body weight attained was recorded in birds that followed the 9-day FUTOPM diet (0.91 kg/bird), followed closely by those that followed the 6-day FUTOPM diet (0.89 kg/bird). Birds that followed the control and 3-day FUTOPM diets had equal final body weights of 0.84 kg/bird. The cost of feed consumed was lowest in the 6-day FUTOPM diet (₦785.75), followed by the 9-day FUTOPM (₦812.77), 3-day FUTOPM (₦872.30), and control diets (₦908.03). The total production cost was therefore lowest in the 6-day FUTOPM diet (₦2244.25) and highest in the control diet (₦2366.53). The returns from selling the birds were also highest in the 6-day FUTOPM diet (₦710.75), followed by the 9-day FUTOPM diet (₦676.23). The control and 3-day FUTOPM diets realized lower returns. The cost-benefit ratio again emphasized the economic efficiency of fermented diets, which attained its maximum in the 6-day FUTOPM diet (1.32), followed by the 9-day FUTOPM diet (1.30), 3-day FUTOPM diet (1.13), and control diet (1.12).

The observed economic benefit agrees with earlier works that the use of fermented agro-industrial residues as a nutrient supplement for poultry can be economically sound. This is according to Alagbe *et al*. (2021), who assert that fermentation increases the bioavailability of nutrients, as well as decreases feed costs, hence improving the economic efficiency of poultry production. This has been echoed by other authors, namely, Adeyeye *et al*. (2017), Akoh & Jimoh (2024), as well as Okpe *et al*. (2025), who noted that fermented agro-industrial residues can be used to decrease production costs without compromising growth rate.

Table 2: Performance of broiler chickens fed diets containing 20% inclusion level of FUTOPM at varying fermentation periods at starter phase (0-4 weeks)

	Dietary Treatment					
Parameters	**Control**	**3-days**	**6-days**	**9-days**	**SEM**	**P-value**
Initial Body Weight (g/bird)	41.43	41.43	41.42	41.42	0.00	0.96
Final Body Weight (g/bird)	884.88^{b}	882.38^{b}	935.00^{ab}	953.33^{a}	10.45	0.04
Weight Gain (g/bird)	843.45^{b}	840.95^{b}	893.58^{ab}	911.91^{a}	12.29	0.03
Daily Weight Gain (g/bird)	30.12^{b}	30.03^{b}	31.91^{ab}	32.57^{a}	0.44	0.03
Total Feed Intake (g/bird)	1172.91^{a}	1153.86^{a}	1062.80^{b}	1109.19^{ab}	11.55	0.02
Daily Feed Intake (g/bird)	41.89^{a}	41.21^{a}	37.96^{b}	39.61^{ab}	0.41	0.02
Feed Conversion Ratio	1.39^{b}	1.38^{b}	1.19^{a}	1.22^{a}	0.03	0.02
Feed Cost/Kg gain (N/kg)	1077.77	1039.33	878.86	889.90	27.84	-
Mortality (%)	0.42	1.09	0.00	0.00	0.20	-

^{ab} means on the same row with different superscripts are significantly different ($P<0.05$) SEM: Standard Error of Mean; FUTOPM: Fermented Urea Treated Orange Peel Meal

Table 3: Economics of production of broiler chicken fed diets containing 20% inclusion level of FUTOPM at varying fermentation periods at starter phase (0-4 weeks)

	Dietary Treatment				
Parameters	**Control**	**3-days**	**6-days**	**9-days**	**SEM**
Cost of Day-Old Chicks (N)	1250.00	1250.00	1250.00	1250.00	0.00
Cost of Experimental Diet (N/kg)	772.79	755.24	737.79	730.58	7.82
Total Feed Consumed (kg/bird)	1.17	1.15	1.06	1.11	0.01
Total Weight (kg/bird)	0.84	0.84	0.89	0.91	0.02
Cost of Labour (N)	160.00	160.00	160.00	160.00	0.00
Cost of Vaccine/ (N)	15.00	15.00	15.00	15.00	0.00
Cost of Drugs (N)	20.00	20.00	20.00	20.00	0.00
Other Cost of Production (N)	13.50	13.50	13.50	13.50	0.00
Cost of Feed Consumed (N)	908.03	872.30	785.75	812.77	8.81
Total Cost of Production (N)	2366.53	2330.80	2244.25	2271.27	8.81
N3000/Kg Body Weight (N)	2655.00	2640.00	2955.00	2947.50	51.91
Selling Price Realized (N)	288.47	309.20	710.75	676.23	52.63
Cost Saving	0.00	20.73	422.28	387.76	14.34
Cost Benefit Ratio	1.12	1.13	1.32	1.30	0.02

SEM: Standard Error of Mean; FUTOPM: Fermented Urea Treated Orange Peel Meal

4. CONCLUSION

Fermented Urea-treated orange peel meal, especially when the fermentation period is prolonged, has been found to remarkably improve growth rate and feed efficiency of broiler chickens in the starter phase, and also simultaneously decrease production costs and enhance profitability. The findings of this study clearly show that the supplement of urea and microbial fermentation has been an effective method for increasing the nutritional quality of orange peel in the growth phase. This method of feeding has been an effective and eco-friendly means of increasing the nutritional quality of orange peel for broiler chicken production.

Acknowledgments

The authors acknowledge Dr. N. Adeleke, Mr and Mrs. Akanbi, the technical support provided by the staff of the Department of

Animal Science Teaching and Research Farm and the Department of Microbiology, Ahmadu Bello University, Zaria, during the conduct of the experiment and laboratory analyses. Appreciation is also extended to all individuals who contributed to data collection and routine management of the experimental birds.

Author Contributions

Conceptualization and experimental design were carried out by O.M.A. and T.S.O. Methodology, laboratory procedures, and data collection were performed by O.M.A. Supervision of the experiment was performed by T.S.O., M.A., S.S.N., and H.I.A. Data analysis and interpretation were undertaken by O.M.A. The original draft of the manuscript was written by O.M.A., while all authors contributed to manuscript review, editing, and approval of the final version.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or nonprofit sectors.

Conflict of interest

The authors declare that they have no conflicts of interests, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval

Ethical approval for the use and care of experimental animals was obtained from the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC) prior to the commencement of the study. All experimental procedures complied with institutional and international guidelines for animal welfare (Ethical approval number: ABUCAUC/2023/147).

Informed consent

Not applicable.

Data availability

All data supporting the findings of this study are embedded within the manuscript. Additional information may be made available from the corresponding author upon reasonable request.

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