Economic Effectiveness of Feeding Pomegranate (*Punica granatum L.*) Peel Powder Supplemented Diets to Broiler Birds

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Abstract**—**The economic effectiveness of feeding Cobb-500 broiler birds with pomegranate peel powder (PPP) supplemented diets was evaluated. The birds (n=432) were replicated in four pens and fed the non-supplemented diet, α-tocopherol acetate (vitamin E) diet, or different dietary levels of the PPP (2, 4, 6 and 8 g/kg). The results revealed that feed cost per kg weight gain was reduced in the control diet and at the 2 g/kg of the PPP inclusion, whereas the cost of total feed consumed was lower in the control studies. Higher ($p<0.05$) revenue was recorded in the 2 g/kg PPP, whereas the vitamin E group recorded the highest ($p<0.05$) income when compared with other groups. Evidently, the cost of production was cheaper when PPP was supplemented at 2 and 4 g/kg. It was concluded that supplementing PPP at all the dietary levels was more economical than vitamin E supplementation. Supplementing PPP at 2 and 4 g/kg inclusion levels was as effective as the negative control diet in reducing the cost of broiler production.

Keywords**—**Expenditure, pomegranate peel powder, performance, revenue, profitability

I. Introduction

Nowadays, people engage in economic ventures such as broiler production, with the sole aim of making profits at minimized production cost. On the other hand, there is a concern of feeding natural additives to broiler birds, in lieu of compounds with synthetic components. These synthetic compounds have been shown to have negative effect on the health of human consumers of broiler products. To meet the demands of offering safe products to consumers whilst minimizing cost, broiler producers keep making concerted efforts to explore the use of medicinal plants which have antioxidant properties. Findings from various studies have shown that medicinal plants improve the productive performance of birds [1, 2, 3, 4]), pullet chicks [5], rabbits [6, 7], extends the shelf-life of stored meat products [8, 9], in addition to their overall promise of enhancing public health.

Recently, research done to ascertain the health benefits of consuming pomegranate fruit has somewhat increased. Pomegranate fruit, often known as "balausta", is a pulpy berry made up of several small seeds (prismatic shape), pulpy cover (testa), woody tegmen without albumin, straight embryo and cotyledons that are all enclosed in the inside of the leathery peel [10, 11].

Pomegranate fruit is generally used to treat and cure aphtae, ulcers, diarrhea, acidosis, dysentery, hemorrhage, microbial infections, and respiratory pathologies [12]. The aril, seed, and juice are the edible portions of the fruit, while the peel is the inedible portion. Pomegranate peel is a functional product with copious amount of minerals and vitamins, coupled with its organoleptic and nutritional properties [13]. Due to its health promoting effects, pomegranate peel has found relevance in the food, beverage, textile, energy, pharmaceutical and cosmetic industries where it is used for various purposes [14]. The aim of this study was to determine the cost implication of feeding pomegranate peel powder (PPP) diet to Cobb-500 broiler birds.

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II. Materials and Methods

A. Ethical Approval, Study Location and Duration

The ethical recommendations for the study were based on approval obtained from the University of Fort Hare Research Ethics Committee; protocol number: MUC061SAKU01). Approval was also obtained from the Department of Agriculture, Forestry and Fisheries (DAFF), South Africa, under section 20 Animal Diseases Act, 1984; reference number: 12/11/1/4. The experiment was conducted at Fort Cox College of Agriculture, Middledrift, Eastern Cape South Africa for 5 weeks, between April-May 2019.

B. Procurement and Preparation of Pomegranate Peel Powder

The pomegranate ('Wonderful' variety) peels were procured fresh from the post-harvest research center of Stellenbosch

University. Oven-drying of the peels was done at 60 °C based on previously described protocol [15]. After that, the dried peels were milled, and the resulting powder meal was used in formulating the experimental diets.

C. Experimental Birds

A total of 432-day-old Cobb-500 broiler chicks were used for the study. At the beginning of the feeding trial, the chicks were randomly selected, weighed, and placed into six different treatment groups that were further replicated in four pens that held 18 chicks each. Each pen had a good number of feeding and drinking troughs to ensure sufficient access to water and feed for each bird. The initial temperature of the broiler facility where the birds were housed was 35 °C. The temperature was gradually reduced by 2-3 °C until it was 22 °C, and then it was kept at this rate till the birds were euthanized. A 23-24hr lighting cycle was provided for the first week of the feeding trial, after which, a stepwise lighting was maintained then for the remaining days. Routine vaccination (Gumboro disease vaccine on days 7 and 14), and New castle disease vaccine on days 21 and 28) was administered to the birds.

D. Experimental Diets

A corn-soybean basal diet which served as the negative control diet (i.e., Dietary treatment 1; DT1) was formulated at both starter (0-21) and grower-finisher phases to meet or exceed the nutrient requirements of the birds, based on the recommendations of the National Research Council [16]. The basal diet was supplemented with vitamin E (α-Tocopherol acetate) at 200 g per tonne and was designated as the positive control diet (i.e., Dietary treatment 2; DT2). The PPP was supplemented in the basal diet at varying dietary inclusion levels of 2, 4, 6 and 8 g/kg respectively, and were designated as dietary treatments 3, 4, 5 and 6 (DT3, DT4, DT5 and DT6). All the diets were isocaloric and isonitrogenous and were offered *ad libitum* to the birds in a mash form. There was a daily routine of monitoring the birds in each pen, ensuring the removal of dead birds, and making necessary adjustments for the feed consumption parameters. Fresh and clean water was also provided to the birds daily as required. The ingredients and nutrient composition of the experimental starter and finisher diets are shown in Tables I and II.

E. Chemical Analyses

The experimental diets were analyzed to determine their proximate (chemical) contents of crude protein, ash, ether extract, acid detergent fibre and neutral detergent fibre based on the methods described by AOAC [17]. The proximate composition of the experimental diets is shown in Table III.

F. Determination of Performance and Cost Parameters

Following the initial weighing at placement of the birds into experimental pens, weighing was done weekly until the day the birds were slaughtered. The daily feed intake and weekly weight data was used to calculate the feed conversion ratio. The economic implication of feeding PPP diets to broiler birds was determined by conducting a cost-benefit analysis, in which case, cost parameters such as the cost of procuring the birds, cost of feeding etc. was evaluated.

TABLE I
INGREDIENTS AND NUTRIENT COMPOSITION OF STARTER DIETS (0-21 DAYS)

Ingredients	Experimental diets					
	1	2	3	4	5	6
Maize	48.8	48.8	48.8	49.0	49.0	49.0
Soybean full fat	28.5	28.5	28.5	29.5	29.5	29.5
Soybean meal (CP 44%)	13.3	13.3	13.2	11.8	11.6	11.4
Fish meal 65	4.00	3.98	3.90	3.90	3.90	3.90
L-lysine Hcl	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.40	0.40	0.40	0.40	0.40	0.40
L-threonine	0.16	0.16	0.16	0.16	0.16	0.16
Vitamin mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Limestone	1.46	1.46	1.46	1.46	1.46	1.46
Salt	0.20	0.20	0.20	0.20	0.20	0.20
Monocalcium phosphate	1.23	1.23	1.23	1.23	1.23	1.23
Sodium bicarbonate	0.16	0.16	0.16	0.16	0.16	0.16
Oil-sunflower	1.50	1.50	1.50	1.50	1.50	1.50
PPP	-	-	0.2	0.4	0.6	0.8
α-tocopherol acetate	-	0.02	-	-	-	-
Calculated contents %						
AMEn (MJ/Kg)	13.2	13.2	13.2	13.1	13.1	13.1
Crude protein	24.1	24.1	23.9	23.7	23.7	23.6
Crude fibre	4.56	4.56	4.53	4.14	4.08	4.02
Ether extract	5.54	5.54	5.54	5.57	5.57	5.57
Calcium	1.03	1.03	1.03	1.03	1.03	1.03
Available phosphorus	0.44	0.44	0.44	0.44	0.44	0.44
Lysine	1.44	1.44	1.43	1.42	1.41	1.41
Threonine	0.89	0.89	0.89	0.89	0.88	0.88
Tryptophan	0.28	0.28	0.28	0.28	0.28	0.28

a Vitamin+ mineral premix provided (per kg of feed): 8160 IU vit A, 1700 IU vitamin D3, 30.6 IU vitamin E, 2.7mg vitamin K3, 205mg vitamin B1, 2.03mg vitamin B2, 27.2mg niacin, 10.2mg calcium pentothenate, 2.02mg vitamin B12, 4.1mg vitamin B6, 1.7mg folic acid, 0.068mg biotin, 120mg ronozyme P500, 350mg choline, 0.08mg I, 0.34 mg Co, 0.2mg Se, 70mg Mn, 70mg Zn, 6mg C and 50mg Fe. b Pomegranate peel powder meal was provided by Postharvest Research Centre, Stellenbosch University South Africa, c Antibiotic growth promoter (α-tocopherol acetate at 200g/ton

of feed), d calculated nutrient levels; e AMEn = Apparent metabolizable energy. CP: Crude protein; VMPx: Vitamin mineral premix; MCP: Monocalcium phosphate; PPP: Pomegranate peel powder; Av. Available.

TABLE II
INGREDIENTS AND NUTRIENT COMPOSITION OF GROWER-FINISHER DIETS (22-35 DAYS)

Ingredients	Experimental diets					
	1	2	3	4	5	6
Maize	58.00	58.00	58.00	58.00	58.00	58.00
Soybean full fat	38.78	36.76	36.58	36.38	36.18	35.98
L-lysine Hcl	0.13	0.13	0.13	0.13	0.13	0.13
DL-methionine	0.32	0.32	0.32	0.32	0.32	0.32
L-threonine	0.05	0.05	0.05	0.05	0.05	0.05
[a] VMPx	0.15	0.15	0.15	0.15	0.15	0.15
Limestone	1.40	1.40	1.40	1.40	1.40	1.40
Salt	0.25	0.25	0.25	0.25	0.25	0.25
MCP	1.32	1.32	1.32	1.32	1.32	1.32
SBC	0.10	0.10	0.10	0.10	0.10	0.10
Oil-sunflower	1.50	1.50	1.50	1.50	1.50	1.50
[b] PPPM	-	-	0.2	0.4	0.6	0.8
[c] α-tocopherol acetate	-	0.02	-	-	-	-
[d] Calculated composition %						
[e] AMEn (MJ/Kg)	13.81	13.81	13.78	13.75	13.72	13.69
Crude protein	19.38	19.38	19.31	19.24	19.17	19.10
Crude fibre	3.34	3.34	3.33	3.32	3.31	3.30
Ether extract	6.86	6.86	6.83	6.79	6.75	6.72
Calcium	1.01	1.01	1.01	1.01	1.01	1.01
Av. Phosphorus	0.37	0.37	0.37	0.37	0.37	0.37
Lysine	1.06	1.06	1.05	1.05	1.04	1.04
Threonine	0.70	0.70	0.70	0.69	0.69	0.69
Tryptophan	0.21	0.21	0.21	0.21	0.21	0.21

a 2.7mg vitamin K3 205mg vitamin B1, 2.03mg vitamin B2, 27.2mg niacin, 10.2mg calcium pentothenate, 2.02mg vitamin B12, 4.1mg vitamin B6, 1.7mg folic acid, 0.068mg biotin, 120mg ronozyme P500, 350mg choline, 0.08mg I, 0.34 mg Co, 0.2mg Se, 70mg Mn, 70mg Zn, 6mg C and 50mg Fe. b Pomegranate peel powder meal was provided by Postharvest Research Centre, Stellenbosch University South Africa, c Antibiotic growth promoter (α-tocopherol acetate at 200g/ton of feed), d calculated nutrient levels, e AMEn = Apparent metabolizable energy, VMPx: Vitamin mineral premix, MCP: Monocalcium phosphate; SBC: Sodium bicarbonate; Av. Available.

TABLE III
PROXIMATE COMPOSITION OF EXPERIMENTAL STARTER (0-21 DAYS) AND FINISHER (22-35 DAYS) DIETS

Diets/phase	CP	DM	EE	Ash	ADF	NDF	Ca	P
0-21 days								
Diet 1	23.24	87.32	8.89	5.34	4.63	14.44	1.41	0.78
Diet 2	23.82	86.21	9.94	6.79	2.70	13.06	1.09	0.60
Diet 3	23.37	86.44	8.86	6.43	4.76	18.24	0.90	0.62
Diet 4	23.91	87.33	7.45	5.47	3.80	14.12	1.38	0.78
Diet 5	23.72	91.30	8.82	6.03	3.88	19.72	1.07	0.82
Diet 6	23.85	94.64	8.90	6.52	4.08	15.71	0.97	0.61
22-35days								
Diet 1	20.05	87.25	8.70	5.16	4.86	20.09	1.36	1.23
Diet 2	20.15	86.20	8.99	9.22	3.01	18.64	1.26	0.71
Diet 3	20.12	86.35	6.54	8.22	3.98	19.83	1.11	1.14
Diet 4	20.30	87.45	6.48	5.23	5.79	23.01	1.48	1.19
Diet 5	20.49	90.44	6.77	5.47	5.82	19.57	1.28	1.38
Diet 6	20.25	92.05	7.23	8.39	6.90	21.85	1.05	1.47

CP: Crude protein; DM: Dry matter; EE: Ether extract; ADF: Acid detergent fibre; NDF: Neutral detergent fibre; Ca: Calcium; P: Phosphorus

G.Statistical Analysis

Data were analyzed based on a one-way analysis of variance technique as described for a completely randomized experimental design using the General Linear Model procedures of SAS [18]. Mean separation was done using Duncan's new multiple range test of SAS (2010), and differences were declared significant at $p<0.05$.

III. RESULTS

Results on the production and cost implications of feeding PPP to broiler birds are shown in Table IV. The production and carcass parameters such as total body weight (TBW), total body weight gain (TBWG), total feed consumed (TFC), feed conversion ratio (FCR), protein intake (PI) protein efficiency ratio (PER) and dressing percentage (DP) were unaffected ($p>0.05$) by dietary PPP supplementation.

Cost parameters such as feed cost (FC) per kg weight gain and cost of total feed consumed (CTFC) were higher ($p<0.05$) in the dietary treatment 2, DT2 (i.e., vitamin E supplemented birds) than in dietary treatment 1, DTI (birds fed basal diet) and birds fed PPP at 2, 4, 6 and 8 g/kg (i.e., DT3, DT4, DT5 and DT6). Birds in the DT2 and DT3 groups had similar

($p>0.05$) FC values, however; the FC of the DT2 birds was lower than those of birds in DT4, DT5 and DT6 groups. Birds in DT2 group also had similar ($p>0.05$) CTFC with the DT3 and DT4 birds, but their CTFC values were lower ($p<0.05$) compared with that recorded in the DT5 and DT6 birds. Revenue was higher ($p<0.05$) in DT3 compared with birds in other groups. Income over revenue was higher ($p<0.05$) in DT2 compared with birds in other groups.

TABLE IV
PRODUCTION AND COST INDICES OF BROILERS FED POMEGRANATE PEEL POWDER (0-35 DAYS)

	Dietary treatments (DT)							
	Performance parameters							
Parameters	DT1	DT2	DT3	DT4	DT5	DT6	SEM	P-value
TBW (kg)	2.09	2.01	2.18	2.14	1.99	2.07	0.04	0.76
TBWG (kg)	2.05	1.97	2.14	2.09	1.95	2.03	28.28	0.37
TFI (kg)	3.09	3.06	3.03	3.06	3.02	3.00	0.04	0.99
FCR	1.50	1.56	1.42	1.46	1.55	1.48	0.13	0.01
PI (g/bird/d)	17.74	17.62	17.58	17.61	17.32	17.33	0.08	0.63
PER (g/g)	3.38	3.25	3.55	3.47	3.29	3.41	0..05	0.46
DP (%)	73.04	71.96	74.17	72.62	72.12	74.46	1.44	0.99
	Cost parameters							
Feed cost/kg	575.73^{e}	751.15^{a}	606.18^{de}	629.84^{cd}	667.07^{b}	697.51^{bc}	14.83	0.00
Bird cost (R)	8.28	8.28	8.28	8.28	8.28	8.28	0.04	1.00
CTFC (R)	1783.61^{d}	2299.84^{a}	1839.2^{cd}	1921.74^{bcd}	2013.2^{bc}	2093.9^{b}	47.62	0.00
Revenue (R)	17.36^{bc}	16.63^{de}	18.04^{a}	17.70^{b}	16.50^{e}	17.13^{cd}	0.14	0.00
Income (R)	1766.24^{c}	2283.21^{a}	1821.1^{c}	1904.03^{bc}	1996.72^{b}	2076.8^{b}	45.72	0.00

TBW = total body weight. TBWG = total body weight gain. TFI = total feed intake. FCR = feed conversion ratio. PI = protein intake. PER = protein efficiency ratio. DP = dressing percentage.

IV. DISCUSSION

Medicinal plants are potent growth promoters and immune system enhancers due to the ability to stimulate appetite, activate immune responses, improve feed intake, endogenous enzyme secretion and colonize the gut [19, 20]. Pomegranate peel is among the spectrum of medicinal plants that enhances health outcomes because of its antimicrobial, antioxidant and immune-modulatory properties which are mainly due to the presence of proanthocyanidins [21, 22]. The absence of dietary effect of PPP supplementation on the growth parameters evaluated are in tandem with the findings of Ahmadipour *et al*. [23] and Rama Rao *et al*. [24]. They reported that PPP did not influence the body weight and feed conversion of broiler birds.

The ultimate intention of broiler producers is to save cost while feeding broiler birds with alternative feed ingredients. Hence, the choice of alternative feed ingredients in broiler nutrition should be guided by the growth enhancing properties, coupled with cost effectiveness of the additives. From the results on cost parameters, it was evident that the cost of production was cheaper when PPP was supplemented at 2 and 4 g/kg. Interestingly, supplementing PPP at all the dietary levels was more economical than the vitamin E supplementation.

Authors are not aware of existing literatures on the dietary effects of PPP inclusion on the economics of production in broiler diets. Nevertheless, in previous reports, supplementing broiler diets with medicinal plants was more economical than the control diet due to the higher relative economic efficiency value recorded [25, 26]. The record of higher economic efficiency that accrues from medicinal plant supplementation had been attributed to the improved feed conversion ratio and reduced feed cost per kg weight gain that results when birds consume these diets. Furthermore, an increase in feed cost per kg weight gain had earlier been linked to poor feed utilization efficiency and poor growth rate of birds that consumed the alternative feed ingredients [27]. However, the increase in feed cost per kg weight gain recorded at the 6 g/kg and 8 g/kg inclusion levels of PPP cannot be entirely linked to these factors as the birds on these diets had comparable weight gain and feed conversion ratio with birds on the control diet.

V. CONCLUSION

The results of this study revealed that supplementing PPP at all the dietary levels was more economical than the vitamin E supplementation. Supplementing PPP at 2 and 4 g/kg inclusion levels was as effective as the control diet in reducing the cost of production.

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