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Effects of Inclusion of Mango Peel Waste in Diets of Layer Chickens on Performance and Egg Quality in Kenya

Everlyne Nawiri [1,*], Joyce G. Maina [1], Judith A. Atela [1], Jane L. Ambuko [2] and Benjamin Kyalo [1]

1 Department of Animal Production, Faculty of Veterinary Medicine, University of Nairobi, Nairobi P.O. Box 29053-00625, Kenya; joyce.maina@uonbi.ac.ke (J.G.M.); judith.atela@uonbi.ac.ke (J.A.A.); kyalob@uonbi.ac.ke (B.K.)

2 Department of Plant Science and Crop Protection, University of Nairobi, Nairobi P.O. Box 29053-00625, Kenya; jane.ambuko@uonbi.ac.ke

* Correspondence: nawirieve@students.uonbi.ac.ke

Abstract: Alternative ingredients for the manufacture of poultry feeds need to be identified to meet the growing demand. A 42-day feeding trial was conducted to investigate the effects of the inclusion of mango peel waste in layer chicken diets on performance and egg quality. This study involved one hundred and fifty Isa Brown layer chickens aged 60 weeks. These chickens were assigned to five treatments with graded levels of mango peels: 0% (Treatment 1), 3.5% (Treatment 2), 7% (Treatment 3), 14% (Treatment 4) and 28% (Treatment 5), using a completely randomized design (CRD). Daily egg production was recorded, and weekly measurements included feed intake, specific gravity, egg weight, shell weight and shell thickness. Notably, Treatment 5 exhibited the highest feed conversion ratio (3.09) and Roche yolk color (RYC) fan score (14.3), which was significantly ($p < 0.05$) different from Treatment 1, with values of 2.36 and 12.4, respectively. Layer chicken fed on T1 had the highest egg weight and egg thickness (6.6 g and 0.44 mm, respectively), differing significantly ($p < 0.05$) from Treatment T5 eggs (6.3 g and 0.41 mm). It was concluded that mango peels could substitute maize in layer chicken diets up to 7% without affecting production and egg quality. Mango peels are recommended for partial substitution of maize in layer chicken diets and as natural egg yolk pigment to impart the yellow yolk desired by consumers.

Keywords: layer chicken; mango peels; agro-processing byproducts; egg production; egg weight; shell thickness; feed intake; substitute; yolk color

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1. Introduction

In the pursuit of sustainable poultry nutrition, the past decade has witnessed a remarkable surge in poultry feed production, driven by the growing demand from the poultry industry [1]. Simultaneously, the fruit processing sector grapples with the disposal of substantial waste, particularly mango peels [2,3]. This manuscript delves into the innovative utilization of mango peel waste as a dietary supplement in layer chicken feeds, exploring its subsequent effects on production performance and egg quality parameters. By addressing a significant research gap, this study evaluates the viability of mango peel waste as a cost-effective and environmentally friendly feed alternative, potentially enhancing the health and productivity of layer chickens.

The increasing global human population has led to a higher demand for animal proteins. Poultry protein (both meat and eggs) is recognized as an affordable and reliable source of quality protein, energy, vitamins and minerals [4,5]. This has resulted in a growth in demand for feed ingredients for the manufacture of poultry feeds.

Maize (*Zea mays*) has a long history of being used as animal feed and biofuel and is hence grown globally. Preference to maize for feeding poultry is because of its dense energy value, which is higher than other grains, and its high stability in nutrient composition, making it easier to predict its nutrient content, which is important for poultry health and production. Maize has emerged as a staple for most African and Latin American communities, causing stiff food-feed competition. Despite maize's popularity, challenges persist due to high feed costs and the scarcity of quality feeds [6].

Mango (*Mangifera indica*) fruit is one of the most processed fruits globally [7]. During processing, mango peels are a major by-product that mostly go to waste and are therefore easily available for use in other products or consumption when processed further [7]. However, the high cost of traditional maize-based diets poses challenges for poultry productivity. Mango peel waste can play an important role in ensuring feed availability and minimizing the competition in the current chicken feed market [8]. The mango peels contain a high amount of energy and sugar, making them palatable compared to maize, and can therefore be used as an alternative energy source in poultry diets [9]. There have been few studies on the effects of mango peels on layer hen performance and egg quality. We embarked on the current study to fill and enrich the knowledge gap.

2. Materials and Methods

The feeding trial adhered to the guidelines set forth by the Biosafety Animal Use and Ethics Committee and received certification from the Faculty of Veterinary Medicine at the University of Nairobi (Nairobi, Kenya).

2.1. Source and Preparation of Mango Peels

Apple mango variety peels were acquired from the Department of Food Science, Nutrition and Technology at the University of Nairobi as part of the project "Strengthening Africa food Processors" (SAP), and from the Kalamba mango processing plant in Makueni County, Kenya. The choice of the apple mango variety was influenced by their abundance (availability). The other raw materials for formulating layer chicken diets were acquired from a local raw material distributor in Thika town.

Processed (Fermented) Mango Peels

The apple mango peels underwent a two-step process to prepare them for use in formulating the layer chicken diets.

Fermentation: The peels were placed in silage bags and allowed to ferment for 96 h. This step likely enhances their nutritional value and makes them more digestible for the chickens.

Sun drying: After fermentation, the peels were sun-dried until their moisture content dropped below 12%. This low moisture level ensures better storage stability and prevents spoilage.

Once dried, the peels were labeled and stored in bags within a well-ventilated dry store, ready for incorporation in layer chicken diets.

2.2. Experimental Design

This research was conducted at the poultry unit of the Animal Production Department, Faculty of Veterinary Medicine, University of Nairobi. Location coordinates are Latitude 1°15′33.84″ S and Longitude 36°43′30.828″ E. This research involved a feeding trial.

This research employed a completely randomized design (CRD) to assess the effects of processed apple mango variety peels at five graded levels of inclusion (0%, 3.5%, 7.0%, 14% and 28%), with each level replicated five times.

A total of one hundred and fifty Isa Brown laying hens, aged 60 weeks and of similar weight, were selected from a laying flock in the Animal Production Department's poultry unit. These hens were then transferred to an experimental house containing 25 cages, each measuring 192 cm × 216 cm with a height of 240 cm. Each cage held six birds, forming a replicate. The cages were equipped with long trough feeders and waterers sufficient for the six birds. Before the experiment, the birds were dewormed and vaccinated against Newcastle disease. For a period of seven days, the birds were fed a formulated control diet to allow adaptation to experimental diets and conditions.

2.3. Housing

Prior to the onset of the experiment, the house was prepared by thoroughly cleaning with detergent to remove all the dirt, followed by rinsing with clean water and leaving to dry. The house then underwent a comprehensive disinfection process, including spraying the inner roof, walls and floor with a disinfectant solution. Afterwards, it was sealed and left undisturbed for a two-week period to allow the disinfectant to take effect before transferring the birds.

The experimental house featured two elongated sides that remained open, equipped with wire mesh. The design facilitated adequate ventilation and allowed consistent natural lighting for approximately 12 hours each day. The ambient temperature ranged from 20.5 °C at the minimum to 29.5 °C at the maximum.

2.4. Experimental Diets and Nutrient Analysis

Five iso-caloric and iso-nitrogenous experimental diets were formulated based on the NRC [10] nutrient requirements for layer chicken specifications. The diets contained 2750 kcal ME/kg DM, 16% crude protein, 1.2% available phosphorus and 3.2% available calcium. The control diet contained no mango peels, while the other diets contained processed apple mango variety peels at 3.5%, 7%, 14% and 28% of the diet, respectively. In Diet 2, 3.5% of the maize used in the control was removed and substituted with the same quantity of mango peels, while other ingredients were adjusted to balance the diet to the same energy and protein level as the control diet. The same procedure was applied to Diet 3, Diet 4 and Diet 5 by substituting maize with mango peels at 7%, 14% and 28%, respectively, and adjusting other ingredients to ensure the same protein and energy levels as the control diet. The ingredients were mixed homogenously as shown (Table 1); the diets fed to the hens were in mash form.

Table 1. Experimental diets.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Maize grain	59.1	57.0	56.3	55.2	44.3
Mango peel	0.0	3.5	7.0	14.0	28.0
Wheat pollard	13.0	13.0	10.6	2.6	9.0
Palm oil	1.0	1.1	1.0	1.0	1.0
Soybean meal	13.8	13.1	13.9	16.6	14.8
Caridina niloticus (Ochong'a)	5.0	5.0	5.0	5.0	5.0
L-Lysine	0.1	0.1	0.1	0.1	0.1
DL-Methionine	0.1	0.1	0.1	0.1	0.1
DCP	0.1	0.1	0.1	0.1	0.1
Limestone	7.0	6.0	5.2	4.6	5.6
Common salt	0.2	0.2	0.2	0.2	0.2
Vitamin–Mineral premix	0.3	0.3	0.3	0.3	0.3
Enzyme	0.1	0.1	0.1	0.1	0.1
Mycotoxin binder	0.1	0.1	0.1	0.1	0.1
TOTAL	99.9	100.0	100.0	100.0	100
Calculated nutrient composition					
ME (kcal/kg)	2750.0	2750.0	2750.0	2750.0	2750.0
NFE	66.8	66.0	64.7	64.9	64.8
Na%	0.3	0.3	0.3	0.3	0.3
Cl%	0.4	0.4	0.4	0.4	0.4
Lys%	1.0	1.0	1.0	1.0	0.9
Meth%	0.6	0.6	0.6	0.6	0.5

Diet 1—0% mango peel (control); Diet 2—3.5% mango peel; Diet 3—7% mango peel; Diet 4—14% mango peel; Diet 5—28% mango peel. Cost (Ksh/kg): Diet 1 = 43.9; Diet 2 = 43.9; Diet 3 = 43.7; Diet 4 = 44.8; Diet 5 = 44.3.

The proximate composition of the diets was analyzed based on AOAC [11] standards.

2.5. Experimental Procedure and Production Performance Data

Layer chickens at 60 weeks of age were adapted to a control diet for one week with water and feed provided ad libitum. At the end of one week, one hundred and fifty birds were weighed, and only birds with an average weight of 2.0 kg were selected, labeled and randomly allocated in the cages, with each cage carrying six birds. At the beginning of the second week, the layer hens were put on experimental diets for six weeks. Data collection was carried out during the experimental period.

2.5.1. Feed Intake

At the beginning of each week, 6 kg of feed was carefully weighed and put in labeled buckets for each replicate. The buckets were covered to prevent dust and spillage. Every morning, the feed troughs were filled to three-quarters capacity using the feed from the buckets. At the end of the week, any remaining feed in troughs was returned to the buckets, weighed and recorded. The weight of the feed in the bucket at the beginning of the week was subtracted from the weight at the end of the week. This difference represented the total feed consumed by the birds in that replicate during the week.

The weekly feed intake was determined by the following method:

$$(\text{Total weekly feed offered} - \text{Total weekly feed refused}).$$

2.5.2. Hen-Day Egg Production

Eggs were collected three times per day at 9.00 a.m., 11.00 a.m. and 4.00 p.m. to avoid breakages and recorded daily. The hen-day egg production (%) was calculated weekly using the method of Phillipe et al. [12].

$$\text{Total number of hen-day} = \text{total number of live birds in the month} \times \text{number of days in a month}$$

$$\%\ \text{Hen day egg production} = \frac{(\text{Total number of eggs laid in a period})}{\text{Total hen day}} \times 100$$

2.5.3. Feed Conversion Ratio (FCR)

The feed conversion ratio (efficiency of feed use) was determined using the following formulae: average feed intake was recorded weekly for six consecutive weeks.

$$\text{FCR} = \frac{\text{Average weekly feed intake per treatment (kg)}}{\text{Total egg mass per treatment (kg)}}$$

2.6. Assessment of Egg Quality Parameters

From each replicate, 3 eggs were randomly selected, resulting in a total of 75 eggs. These eggs were used for assessing various egg quality parameters such as egg weight (egg mass), egg shell weight, egg shell thickness, egg specific gravity and egg yolk color. These evaluations were performed weekly while the birds were on experimental diets.

2.6.1. Egg Weight

Egg weight was determined using a 0.0001 g precision digital scale. Egg mass was computed by multiplying the weight of the eggs by the number of eggs produced during the experimental period per treatment.

2.6.2. Egg Specific Gravity

The specific gravity (egg breaking strength) of the eggs was determined using a non-destructive method, that is, by dipping the 75 eggs in saline solutions with different concentrations. Nine saline solutions were prepared by dissolving a specific amount of common salt (sodium chloride) in three liters of water (Table 2) with a specific gravity ranging from 1.060 g/cm^3 to 1.100 g/cm^3 at a gradient of 0.005. The eggs were then immersed in each of the saline solutions, beginning with 1.060 g/cm^3 (lowest) to 1.000 g/cm^3 (highest) concentrations. The specific gravity of each floating egg was recorded to correspond to the solution in which the egg floated.

Table 2. Weight of salt dissolved in three liters of water for a given specific gravity.

NaCl (g)	Specific Gravity (g/cm^3)
276	1.060
298	1.065
320	1.070
342	1.075
365	1.080
390	1.085
414	1.090
438	1.095
462	1.100

2.6.3. Egg Shell Thickness

Shell thickness was assessed directly by measurement, and the recording of shell thickness was measured using a 0.001 mm paper thickness micrometer with a convex anvil on one arm to reduce errors resulting from shell curvature. Three measurements were taken: at the pointed end, equator and air sac regions, and the average of the three was recorded as the shell thickness.

2.6.4. Egg Yolk Color

The eggs used for the determination of shell strength were broken into a Petri dish, and the yolk color was visually identified using a Roche color fan with a scale ranging from 1 to 16. The most yellow eggs ranged between 9 and 16, medium yellow between 5 and 8 and pale yellow between 1 and 4.

2.7. Statistical Analysis

The data obtained from layer chicken performance and egg quality parameters were subjected to one-way analysis of variance (ANOVA) using GenStat statistical package version 14. Significant differences in treatment means were determined using Tukey's multiple comparison procedure, with the level of significance set at $p < 0.05$.

3. Results and Discussion

3.1. Experimental Feed Proximate Analysis

The chemical composition of experimental layer diets is as shown in Table 3. The dry matter content of the diets was between 88.5% and 90%, while the crude protein content for all the diets was approximately 16%, the CF% content was between 8.6 and 5.6 and the EE% was between 3.7 and 3.2. The calcium level was an average of 3.5%, while the phosphorus level was 0.7%; these levels are optimum for layer chickens. The NFE% of the diet formulations was found to range between 66.8 and 61.8, and the ME was 2750 kcal/kg, showing that mango peels can be used as an important source of energy in poultry diets. The diets with the highest level of mango peels included had the highest CF and EE. The proximate composition of CF, ether and NFE varied depending on the level of mango peels included in the diet.

Table 3. Chemical composition of experimental diets.

Parameter	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Dry matter (%)	90.1	89.1	88.6	88.5	88.5
Crude protein (%)	16.4	16.1	16.3	16.1	16.2
Crude fibre (%)	5.6	5.8	6.7	7.4	8.6
Ether extract (%)	3.4	3.6	3.2	3.6	3.7
NFE (%)	66.8	66.0	64.7	64.9	61.8
Calcium (%)	3.5	3.5	3.4	3.5	3.5
Phosphorus (%)	0.6	0.7	0.8	0.7	0.7
ME (kcal/kg)	2750	2750	2750	2750	2750

%—percentage; NFE—nitrogen-free extract; Diet 1 (control); Diet 2 (3.5% mango peel); Diet 3 (7% mango peel); Diet 4 (14% mango peel); Diet 5 (28% mango peel).

3.2. Effect of Mango Peel Supplementation on Layer Chicken Performance

There were no significant ($p > 0.05$) effects between the layers fed on the control and those fed diets containing mango peels on mean weekly egg production, hen-day egg production, mean weekly egg weight and mean weekly egg mass, as shown in Table 4.

Table 4. Egg production parameters.

Parameter	T1	T2	T3	T4	T5	Mean	SEM	*p*-Value
Egg production (No.)	25.6	24.0	24.0	24.2	22.6	24.2	1.62	0.19
% HDEP	85.2	80.1	80.1	80.5	75.6	80.3	3.84	0.19
Mean weekly egg weight (gm)	67.13	67.18	67.60	67.51	67.12	67.3	1.15	0.99
Mean weekly egg mass (kg)	2.41	2.26	2.28	2.28	2.14	2.3	0.08	0.28
Mean weekly feed Intake (kg)	5.46 ^{a}	5.52 ^{a}	5.75 ^{ab}	5.93 ^{b}	6.37 ^{c}	5.8	0.11	<0.001
Mean weekly FCR	2.36 ^{a}	2.59 ^{ab}	2.7 ^{ab}	2.75 ^{ab}	3.09 ^{b}	2.69	0.14	0.01

Means with different superscripts in the same row differ significantly at $p < 0.05$. T1—Treatment 1; T2—Treatment 2; T3—Treatment 3; T4—Treatment 4; T5—Treatment 5; SEM—standard error of deviation; HDEP—hen-day egg production; FCR—feed conversion ratio.

Birds fed on Treatment 5 (28% mango peels) had the highest (poorest) feed conversion ratio (3.09) and feed intake (6.37 kg), which was significantly ($p < 0.05$) different from that of birds fed on the control diet (FCR 2.36 kg and feed intake 5.46 kg).

3.2.1. Egg Production/Hen-Day Egg Production

The percentage hen-day egg production shown in Table 4 above declined as levels of mango peels increased in the diets, but the decline was not significant ($p > 0.05$). Birds fed on Treatment 1 (control) had the highest production (85.16%), compared to 75.56% of birds fed on Treatment 5 (28% peels). This can be attributed to increasing levels of crude fiber from T1 to T5 (5.6%; 8.6%), respectively, which had a dilution effect on nutrients in the diet, reducing availability and absorption of nutrients, hence resulting in an insignificant decline in production level.

The findings of this study agree with those of Lokaewmanee et al. [9], who reported that mango peel supplementation in laying hens' diet had no significant effect on hen-day egg production in the different treatment groups. The findings of this study further disagree with those reported by Barry et al. [13], who investigated the effects of mango waste-based diets on performance and egg quality of the Isa Brown breed of hens and found that mango waste (peels and seeds) supplementation in laying hen diets significantly increased egg production, which peaked on the second week in treatment groups given a mango–maize feed mixture, but control groups given corn and maize diets laid a higher number of eggs throughout the four weeks.

3.2.2. Feed Intake

Average daily feed intake increased significantly ($p < 0.05$) from the control (Treatment I) to Treatment 5. Birds that fed on Treatment 5 had the highest weekly feed intake of 6.368 kg, which differed significantly from Treatment 1 (control), which had an average feed intake of 5.463 kg, hence the lowest feed intake. The feed intake increased with an increase in levels of mango peels across the treatment groups. This finding can be attributed to the high level of fiber in Treatment 5, resulting in the dilution of nutrients, including energy sources; as a result, the birds had to be fed more to compensate for the energy deficit and other nutrients. Findings of this study agree with those of Tyohemba and Sheidi [14], who investigated the effect of high-feed and low-feed efficient diets on layer hens and reported an increase in feed intake when layer quails and hens were fed on high-fiber diets. The findings of this study differ from those reported by Emshaw et al. [15], who reported a decline in feed intake in Cobb broilers; layer hens can behave the same.

3.2.3. Feed Conversion Ratio (FCR)

Results from the current study indicate that the inclusion of mango peels significantly ($p < 0.05$) affected the average weekly FCR. Treatment 5 (3.09) had the highest (poorest) and Treatment 1 (2.36) had the lowest (best) FCR, respectively. The highest FCR in Treatment 5 is associated with the high feed intake observed in T5; the same is reflected in the other treatment groups compared to T1. The current results were similar to the findings of Tyohemba and Clark [14–16], who found a significant effect on feed intake when feeding high-feed and low-feed efficient diets to layer hens.

3.2.4. Egg Weight

In the current study, it was observed that mango peels had no significant ($p > 0.05$) effect on egg weight and egg mass. The outcome of this study is in agreement with that reported by Lokaewmanee et al. [9], who reported no effect of feeding mango peels on egg weight.

3.3. Effect of Mango Peels on Egg Quality Parameters

Table 5 shows the effects of the inclusion of mango peels on egg quality. The mango peels significantly ($p < 0.05$) affected egg yolk color, as shown in Table 5, with birds fed on the Treatment 5 diet having the highest score (deepest yellow) (14.29), which was significantly ($p < 0.05$) different from that observed in birds fed on Treatment I (12.38).

Table 5. Egg quality parameters.

Parameter	T1	T2	T3	T4	T5	Mean	SED	*p*-Value
Yolk color	12.38 ^{a}	13.47 ^{b}	13.80 ^{bc}	14.13 ^{bc}	14.29 ^{c}	13.614	0.1667	<0.001
Shell weight(g)	6.626 ^{b}	6.485 ^{ab}	6.36 ^{ab}	6.357 ^{ab}	6.260 ^{a}	6.418	0.1047	0.007
Shell thickness(mm)	43.75 ^{b}	43.12 ^{ab}	41.07 ^{a}	41.75 ^{ab}	41.35 ^{a}	42.21	0.804	0.003
Specific gravity(g/cm^3)	1.091	1.055	1.088	1.089	1.087	1.0819	0.02106	0.080

Means in the same row with different superscripts differ significantly at $p < 0.05$. T1—Treatment 1; T2—Treatment 2; T3—Treatment 3; T4—Treatment 4; T5—Treatment 5; SED—standard error deviation.

The shell weight and shell thickness were significantly ($p < 0.05$) affected by the mango peels, with T1 and T5 having 6.626 g and 6.260 g and 43.75 mm and 41.35 mm as the highest and lowest, respectively. The mango peels, however, had no significant effect on the egg's specific gravity.

3.3.1. Yolk Color

In the current study, the inclusion of mango peels significantly ($p < 0.05$) affected egg yolk color, as shown in Table 5, with T5 and T1 scoring 14.29 and 12.38, respectively. This can be attributed to the higher levels of carotenoids present in mango peels [17], which are responsible for imparting deep yellow–orange yolks in eggs. Feeding laying hens mango peels increased the levels of polyphenols in the egg yolk, thereby increasing the pigmentation observed. Saleh et al. [18] investigated the effect of natural and chemical colorant supplementation on performance, egg-quality characteristics, yolk fatty-acid profile and blood constituents in laying hens and observed an increase in egg yolk color. The findings of this study are, however, contrary to those reported by Lokaewmanee et al. [9], who reported that mango skin supplementation had no significant ($p > 0.05$) effects on the egg yolk color since laying hens are incapable of synthesizing egg yolk pigments.

3.3.2. Shell Weight

Mango peels significantly ($p < 0.05$) affected the shell weight, with chickens fed on T1 having the highest (6.62 g) and those fed on T5 having the lowest shell weight (6.260 g), respectively. There was a general decline in shell weight as levels of mango peels increased. This trend was also observed in shell thickness, with T1 having the highest (43.75 mm) and T5 having the lowest (41.35 mm), respectively. Increasing the mango peel ratio, as in T5, does not increase or improve the egg shell weight. These results differ from those reported by Lokaewmanee et al. [9], who observed no effect of mango peels on egg shell weight. Rusli et al. [19] observed that dietary mangosteen pericarp had a significant ($p > 0.05$) effect on egg shell weight and shell thickness in Lohmann laying hens.

3.3.3. Specific Gravity

Specific gravity is a measure of shell thickness. In the current study, mango peels had no significant ($p > 0.05$) effect on the specific gravity of the eggs; however, all the treatments had a higher specific gravity than the normal recommendation of $1.060/\text{g}^{\text{cm}}$. The findings of this study are contrary to those reported by Lokaewmanee et al. [9], who observed no significant difference in the specific gravity of quail eggs fed on dietary mango peels. Lioliopoulou et al. [20] observed a significant ($p < 0.05$) effect on egg specific gravity on layer hens fed pomegranate peels.

4. Conclusions and Recommendations

In summary, the inclusion of mango peels had no effect on layer chicken performance with respect to egg production, HDEP (hen-day egg production) and egg weight, but had a significant effect on feed intake and FCR. Mango peels significantly improved egg quality parameters with respect to egg yolk color.

To address the continued feed food competition, which is causing scarcity and a subsequent increase in the cost of animal feeds, the authors of this article recommend the use of mango peel wastes to substitute maize grain up to 7% without having a significant effect on layer chicken performance. Mango peel waste is also recommended as a natural egg pigment to substitute chemical carotenoids for use in layer chicken diets to impart the yellow yolk pigment as observed in the current study.

The outcome of the current research shows that there is a need for further research to optimize mango peel inclusion levels in layer chicken diets.

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Data Availability Statement: Data are available on request due to restrictions.

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