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Effect of Apple peel (extract) on the growth performance and health status of Broilers

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The current research was conducted to examine the effects of apple peel at various levels on broiler chickens growth performance and health status. A flock of 180 broilers was managed for 42 days period. Birds were distributed in 4 groups (45 chicks in each group mixed sex). Two replicates for each group. The apple peel was supplemented at the levels of 0% to group A, 2% in group B, 4% (g/b) in group C, and 6% (g/b) in group D. The average feed intake calculated for A, B, C, and D groups were 3810, 3700, 3570 and 3540. All groups' live body weight (BW) was 1750, 1760.0, 1785.0 and 1805.0, respectively. The FCR (feed conversion ratio) calculated of all group was 2.17, 2.10, 1.99 and 1.96, carcass weight was 1050.0, 1100.0, 1150.0, 1200.0, heart weight 15.00, 17.50, 16.66, 16.00 gizzard weight was 32.33, 33.00, 36.00 38.00 and the liver weight was 37.66, 41.00, 41.33 and 45.33, respectively. The net profit Rs. 6.17PKR, 11.5, 19.29 and 30.8/bird was calculated for all the groups. It is determined that economically the broiler reared in group D (diet supplemented with 6% apple peel) showed to be more profitable than other kinds of treatment groups. The health condition of the Broiler have been observed on daily bases including temperature, and weight.

Keywords: Apple peel; broiler; feed conversion ratio; economically; profitable

INTRODUCTION

The poultry farming sector in Pakistan is the most vibrant and organized segment that provides employment to 1.5 million individuals. Poultry farm meat subsidizes 28.0 percent of the total meat production in Pakistan. Agriculture lending banks disbursed Rs 102.1 billion to small farms in the non-farm sector, a negative growth owing to decreasing loan offtake, particularly in the poultry sector. A total of Rs 343.7 billion has been distributed to large farmers, resulting in a 3% increase in revenue (GOP, 2021).

Apple contains several nutrient components as well as minerals, fiber, vitamins that are processed in different forms like dried apple and juices. They are the main sources of phytochemicals which promoted antioxidant capabilities *in vitro* (Boyer and Liu, 2004; Eberhardt et al. 2000). The apple has beneficial effects on health with particular devotion given to the evidence on cardiovascular health and biological effect of apple (Boyer and Liu, 2004; Miuraet al. 2007; Osada et al. 2006). Apple fiber mainly consists of soluble fibers (pectin) that are approximately 3g/100g fresh weight (FW). Pectins are branched side chains and complex polysaccharides that form a short-chain fatty acid by the fermentation of micro flora in the large intestine (Thakur et al. 1997). The fatty acid is absorbed and also metabolized in colonic liver mucosa and in peripheral tissues and makes a relation between pectin consumption that maintain blood, cholesterol concentration and post-prandial glycemic response (Tetens, 2012). Fruits processing industries

produce a large quantity of fruits by-products such as concentrates, flavours, juices, and peel. The processing industry of apples produces 5% sludge and 25%-30% apple peel. Apple peel residues are the main source of carbohydrates and bioactive compounds such as polyphenols that exerts antioxidants. Apple pomace has a high lignin/cellulose that's why its digestibility ratio is very low. It also has a low mineral, vitamins, and protein, which showed low nutritious level and contributed lower profitable value. Presently the residue is used in soil fertilizer due to low digestible protein which is not recommended for animal feed (Rumsey et al. 1978). Recently, *Saccharomyces cerevisiae* has been used to surge the protein level of pineapple waste by Solid-State Fermentation (SSF) with and without nitrogen supplementation (Correia, Magalhães et al. 2007).

The phytochemicals concentration between apple peels and apple flash varies depending on the variety. The antioxidant activity is also different according to the variety of apples. Apple peel contains 6 times greater antioxidant activity when compared to the flesh (Boyer et al. 2004; Eberhardt et al. 2000). In agreement with the polyphenol arrangement, peels bearing apples are healthier in inhibiting cancer cell propagation when compared to apples without the peels (Denis et al. 2013). Technologists and scientists have a challenging opportunity to utilize and face the environmental problem of fresh apple residue (apple pulp) after juice extraction. Apple pulp contains peel, seed, and remaining solid parts (Sanchez et al. 2005).

In the poultry production commercial, nourishing is the most important and expensive remarkable input accounting for 65-70% of the entire product price. Apple peels are another feedstuff for animal nourishing, which can be obtained from local apple, marketplace and apple dispensation industry, suggested to the humans with high blood pressure and different diseases (El-Hack et al. 2018). To eliminate or lower the lack of nutritional factors, and Apple per carp had been preserved for poultry feed (Silas, 2014). The apple peel consists of some the anti-nutritional factors like oxalate, tannins, higher crude fiber ash, phytate, and low crude protein compared to the pulp (mesocarp) which makes it a good feedstuff for animal feeding (Maina, Heidi, and Shagal).

Thus, the objective and considering the importance of apple peel in this study were designed to evaluate the Apple Peels effects on the growth of broilers Chickens and health status by feeding in local conditions and environment.

MATERIALS AND METHODS

A day old, 180 broilers (chicken mixed sex) were bought from the local marketplace of Hyderabad city Pakistan and transported to the poultry investigational station department of poultry husbandry, faculty of animal husbandry and veterinary science Sindh Agriculture University Tandojam. Chick's boilers were separated into 4 groups (45 chicks in each group). Two replicates per treatment were used. The groups were Control group (A) feed basal diet, (B) 2 % apple peel/kg, (C) 4 % apple peel/kg, and (D) 6 % apple peel/kg. Two replaces per treatment were used. All the chicks were reared for 6 weeks in slandered manage mental conditions. The composition of the experimental ratio is described in Table 1.

Table 1: Composition of experimental diet (%) included various levels of apple peel

Ingredients	Treatments			
	A (control)	Group B	Group C	Group D
Rice	25	25	25	25
Maize	24.5	23	23	23
Rice polish	5	5	5	5
Fish meal	9	9	9	9
Soybean meal	7	7	7	7
Guar meal	5	5	5	5
Canola meal	13.5	14.5	14.5	14.5
Sunflower meal	6.5	6	5	4
Rapeseed meal	3.5	3.5	3.5	3.5
Limestone	1	1	1	1
Apple peel	0	1	2	3

Management of chicks

Each boiler chick was allocated one sq. ft. space in the floor housing system. The poultry house was completely dis-infecting by using limestone for over 24 hours. The suggested humidity and temperature were sustained during the experimental time. Litter was used at 2-4 inches deep for every group of broilers. Litter rotating was practiced daily to minimize the gas production in the shed. One-foot candlelight was given using electronic bulbs that were tailored with an upper limit at the height of seven feet. However, a fluorescent tube light/charger was made available to practice at the time of electricity failure.

Brooding

The brooding preparation was accomplished in 2-days earlier than the arrival of one-day-old chicks. One brooder was arranged for every group. In the first week of experimental trials, brooding temperature was kept between 90 to 95 0F and about 50F was reduced each week until the end of the trials. Throughout brooding 40/60-wattelectrical bulbs were feted into an electronic brooder and positioned in the center of each round shape assigned area. One thermometer was located at the elevation of 6-12 inches close to the brooder to record the brooding temperature.

Vaccination

The following vaccine was purchased from (SVPC, Karachi) and stored at 4°C, used from vaccination period to period through several roots of direction (SVPC, 2017).

Growth Performance

Feed was given *ad libitum* to the entire broiler two times a day. Refusal of feedstuff was together from feeders of every group, weighed, and consumed feed was measured every day. Body mass was measured every week through an electronic weighing gage. The following formula was used for the calculation of feedstuff intake or refusal.

$$\text{Feed intake (g/b/d)} = \frac{\text{Total feed offered} - \text{Total feed refused}}{\text{Total-broiler}}$$

Feed conversion ratio

FCR (Feed conversion ratio) was determined on the basis of overall feed used by a broiler chicken for gaining 1 kg weight. FCR was calculated by using the formula

$$\text{FCR} = \frac{\text{Total feed intake}}{\text{Total live body weight gain}}$$

Dressing percentage

At the investigational time (42-days), and 5 broilers from each group we reweighed and slaughtered. Subsequently dressing, the skeleton weight was recorded, and its dressing % was determined through the following formula.

$$\text{Dressing (\%)} = \frac{\text{Carcass weight (kg)}}{\text{Live body weight (kg)}} \times 100$$

Visceral organs

The heart, liver, spleen, gizzard, and proventricular were removed, detached with the help of a scissor and scalpel from each broiler, and were weighed using an electronic balance. Dead birds were composed, mortality was documented, and the death % was considered through the following formula

$$\text{Mortality (\%)} = \frac{\text{Total No. of birds died}}{\text{Total number of birds}} \times 100$$

Economic index

The economic ratio was driven to ascertain the consequence of apple peel on development performance and nutrient maintenance of broiler of each group was documented distinctly, and end of experiment weight gain of each group broiler was noted and financial gain and loss was obtained and determined with the help of given formula

Net returns = income - expenditure

Statistical Analysis

The collected data was examined statistically through statistics computer software Satatix 8.1, 2006). The difference among the treatments was compared by the least significant difference (LSD) test, where necessary. Standard values were measured statistically important when ($p \leq 0.05$) or highly significant when ($p \leq 0.01$).

RESULTS AND DISCUSSION

Apple peel reduced feed consumption

As shown in Figure 1, the broiler exhibited a significant difference ($p<0.05$) in feeding response to different levels of apple peel. Maximum feed intakes were recorded in group A (3810.0 g/b), and minimum feed intake of was recorded in group D (3540.0 g/b) (6 % apple peel/kg). These results showed that apple peel reduced feed intake in broilers (Figure 1).

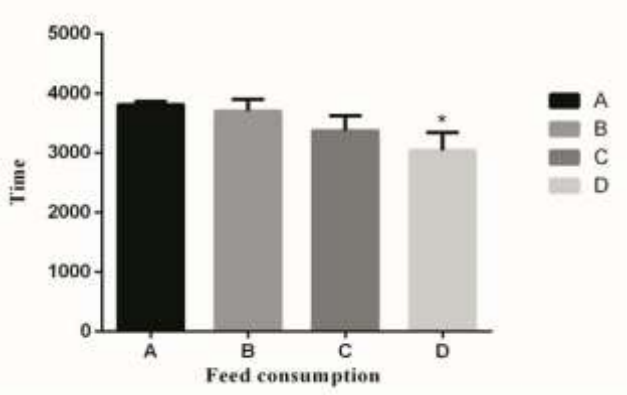

Figure 1: Effects of Apple peel on feed consumption of broiler chickens. The values with a star (*) represent a significant difference (p<0.05)

Apple peel increased broiler body weight

The body weight (live broiler) was mainly influenced by the quality of feedstuff and ingredients of its arrangement.

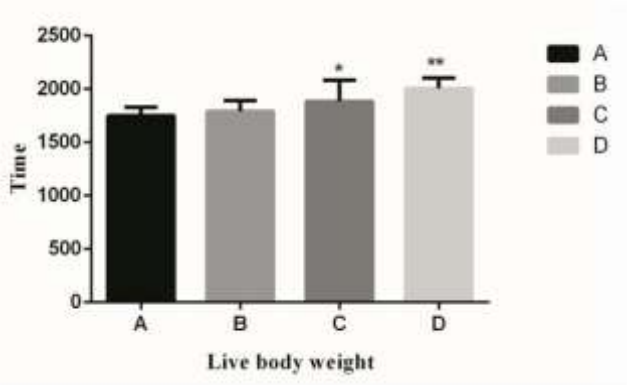

Figure 2: Effects of Apple peel on body weight of broiler chickens. The values with a star (*) represent a significant difference (p<0.05) or (p<0.01).

The result (Figure 2) specified that the live bodyweight of the broiler in this trial diverse meaningfully ($P>0.05$) when the feedstuff was accompanied by apple peel at different levels. It also showed that (group D) gained better growth with the highest live weight of 2005.0(g/b) associated with the regulator group (group A). It has been observed that as the amount of apple peel

supplementation increased, the live body weight of broilers increased. As the amount of apple peel supplementation decreased, the live body weight of broilers decreased. Excessive addition of apple peel resulted in an increase in live body weight in broilers (Figure 2).

Effect of apple peel on FCR

The finding in (Figure 3) showed that the feed change ratio of six weeks broiler gather was pointedly affected by the supplementation of apple peel with various levels. The feed conversion ratio in groups A, B, C, and D was 2.17 ± 0.15, 2.10 ± 0.07, 1.99 ± 0.05, and 1.96 ± 0.03, respectively. Group D showed the highest feed conversion efficacy, followed by the broilers in groups C and B. These findings recommended that broilers' FCR improved with increasing the level of apple peel supplementation in broiler's feed (Figure 3).

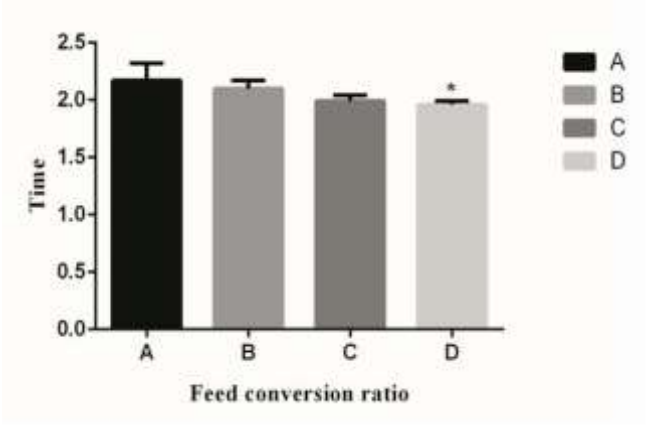

Figure 3: Effects of Apple peel on feed conversion ratio. The values with a star (*) represent a significant difference (p<0.05).

Apple peel increased Carcass weight

The average carcass weight of group A, B, C and D was a 1050.0 (g/b), 1100.0 (g/b), 1150.0 (g/b) and 1200.0 (g/b) respectively. Group D showed maximum carcass weight followed by the broiler in group C when weighed after completion of 43 day experimental period. Group A (control group) didn't show increased carcass weight compared with other groups co-supplemented with an apple peel. The outcomes also exhibited that broilers' carcass weight increased with increasing the levels of apple peel. These results proposed that apple peel improves carcass weight and is not viable economically for broiler production.

Effect of apple peel on the weight of the internal edible organ

The data (Table 2) showed that apple peel did not affect the heart weight significantly (*p<0.05*). The highest 17.50 heart weight was observed in group B followed by the broilers in groups C and D.

These results also indicated that apple peel used as a supplement did not affect broilers' gizzard weight (*p<0.05*). The higher gizzard weight 36.00(g/b), was observed in group D broilers, and the lowest gizzard, 32.33 (g/b) weight was observed in group A.

The data in Table 2 also showed that liver weight in broilers increased up to 45.33 (g/b) in group D when feeding apple peel in higher quantity while the control group lowest was 37.66 (g/b) liver weight. It shows a significant difference (*p<0.05*) when comparing group A with group D (Table 2).

Table 2: Heart, Gizzard and Liver weight of broilers fed various levels of apple peel (g/b).

Organs	Group-A	Group -B	Group C	Group -D
Heart	15.00^{b}	17.50^{a}	16.66^{ab}	16.00^{ab}
Gizzard	32.33^{b}	33.00^{b}	36.00^{a}	38.00^{a}
Liver	37.66^{c}	41.00^{bc}	41.33^{b}	45.33^{a}

SE± = H 0.9354, G 1.2247, L 1.4466
LSD 0.05 = H 2.2889, G 2.9968, L 3.5397
P-value = H 0.1513, G 0.0112, L 0.0110
SE, Standard Error; LSD, Least significant digit; H, Heart; G, Gizzard; L, Live

Mortality of chicks

Chicks died during the whole period of the experiment due to any reason were counted. The cause of all motility was due to chronic respiratory disease (CRD).

Economic gain

The economic limitations of broiler flock nourishing apple peel to all the groups were reserved into justification based on total feed price, live body weight, market sale worth of chicken, and succeeding impact on the net income.

The average feed cost on broilers in groups A, B, C, and D, wasUSD830.76, 0.78, and 0.77/bird. In contrast, the total prices counting the feeding, apple peel, additional medication, litter, limestone, labor, and miscellaneous expenses were recorded as USD 1418.43, 1.44, and 1.50/bird, respectively.

The birds' body weight (live) on average in groups A, B, C, and D was 1.78, 1.76, 1.78, and 1.85kg/bird that produced total income from a broiler on average of USD 1418.43, 1.44, and 1.50/bird, respectively, when marketed at the rate of USD 0.81/kg body weight (live). The net profit was in USD0.031, 0.058, 0.098 and 0.16/bird, respectively. These results showed that group D (6%g/b) was more profitable than the rest of the treatment groups and control group (Table 3).

In poultry farm production professional, nourishing is the most expensive remarkable input that accounts for about 65-70% of the total production price.

Table 3: Apple peel different concentrations effects on the economic parameters of Broiler after 6 weeks

Particulars	Groups			
	A	B	C	D
Day-old chicks	40	40	40	40
Feed consumed	3.81	3.7	3.57	3.54
Rate of feed	43	43	43	43
Feed cost (USD)	0.83	0.80	0.77	0.77
Apple Peel (USD)	0	0.005	0.010	0.015
Medication	8	8	8	8
Litter cost	0.076	0.076	0.076	0.076
Limestone	2	2	2	2
Labour cost	0.18	0.18	0.18	0.18
Misc.	10	10	10	10
Total cost	1.38	1.36	1.34	1.34
Final LBW (kg)	1.78	1.76	1.78	1.85
Marketing price	0.81	0.81	0.81	0.81
Total Income USD	1.41	1.42	1.44	1.49
Net profit (USD)	0.031	0.058	0.097	0.16

Apple peel is another nourishing stuff for animal nursing, riches in potassium and low in sodium, so highly suggested for people with high blood pressure (El-Hack *et al.* 2018). Apple pericarp (peel) has been treated for poultry form used to eliminate/lower the anti-nutritious issues (Silas, 2014). The apple pericarp comprises some anti-nutritious factors like tannins, oxalate and phytate, etc. that might induce adverse effects like depressive growth, condensed food competence, and vigorous tissues damage in the body and ultimately lead to death in birds (chickens) and significant victims in poultry initiative if good processing methods to detoxify these anti-nutritious issues are not carried out. Apple peel comprises higher crude fiber, ash, and low crude protein than the mesa carp (pulp), making it a good alternative feedstuff for animal feeding (Maina et al. 2012).

The present study shows that apple peel 6% (g/b) in feed showed superior results with reduced feed ingesting, lower water intake, increased body weight (live), improved feed conversion competence, increased carcass weight, enlarged heart weight, gizzard weight, and liver weight with highest net profit /b.

A study conducted by Heidarisafar et al. (2016) found that the inclusion of apple peel 100 (g/b) in feed decreased broiler weight gain at the age of 42 days, presence of 50 (g/b) in feed increased gizzard and small intestine weight it mean that formulation diet matches the desired nutrient compete for growth. The results obtained here indicate that feeding up to 50g/b at age of 28-49 days increases fat and decreases fat in serum and has no opposing consequence on broiler performance. The apple meal can be added up to 10% in broiler chicken food without any opposing effect on the performance of the birds, thus enriching the poultry production business (Silas, 2014). The apple peel meal can also be used as an alternate nutritional source in profitable (business) broiler chicken food to decrease the cost of production (Hereinto *et al.* 2016). Apple peels are shown to more efficiently constrain the growth of HepG2 human liver cancer cells than the other apple components. Rome beauty apple peels presented the greatest bioactivity, constraining cell propagation through fifty percent at the low concentration of 12.4 (0.4 mg of peels/mL. The high content of phenolic compounds, antioxidant activity, and anti-proliferative activity of apple peels designate that they may impart health benefits when expended and must be viewed as a treasured source of antioxidants (Wolfe et al. 2003).

Excluding gizzard, heart weights, and liver weight, relative weights of internal organs were not affected by the addition of apple peel in the poultry diet (the data were not exposed here). The increased weight of these organs could be proportional to the increased fiber content in these diets. It has been stated that addition of fiber improved the comparative weight of different sections of the gut tracts in birds particularly gizzard (Jiménez-Moreno et al. 2009; Svihus, 2011). In contrast to our result, (Rizal et al. 2010) stated that the use of fruit juice waste mixture like (carrot, apple, mango, avocado, orange, melon, and tree tomato) in broiler chicken had no outcome on pancreas and gizzard weights. As declared before, apple peel is rich in pectin and additionally nourishing fiber sources with high molecular weight or those having high methoxyl contents could lead to increasing in the liver weight, heart weight, and different internal edible organs, as well as increase in goblet cell numbers which produce mucin and adversely, disturbs absorption (Langhout et al. 1999).

CONCLUSION

It was concluded from the present study that economically the broiler managed in a higher percentage of apple peel showed to be more profitable as compared to the rest of the treatment groups. The present study also demonstrated that apple peel reduced mortality rate in broilers chicken, but for the underlying mechanism, further study will be conducted to know the effect of apple peel on blood biochemistry and different signaling pathways. The apple peels could be used as a food for the chickens to increase the productivity in the chickens.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MAB and SUR designed and performed the experiments and also wrote the manuscript. AM, HUR

performed growth performance activities and data analysis. FU and MNK reviewed the manuscript. All authors read and approved the final version.

REFERENCES

Boyer, J., and R. Liu (2004). Apple phytochemicals and their health benefits. *Nutrition Journal, 3*, 5-5.

Correia, R., M. Magalhães, andG. Macêdo(2007). Protein enrichment of pineapple waste with Saccharomyces cerevisiae by solid state bioprocessing. J. of Sci. andIndus. Res., 6, 259-262.

Denis, M. C., A. Furtos, S. Dudonné, A. Montoudis, C Garofalo, Y Desjardins, and E. Levy (2013). Apple Peel Polyphenols and Their Beneficial Actions on Oxidative Stress and Inflammation. Plos One, 8, e53725.

Eberhardt, M. V., C. Y. Lee, and R. H. Liu (2000). Antioxidant activity of fresh apples. *Nature, 405*(6789), 903-904.

El-Hack, M. E. A., A. A. Swelum, M. A. Abdel-Latif, D. M. Toro, and M. Arif (2018). Pigeon Pea (Cajanus cajan) as an alternative protein source in broiler feed. Worlds Poult Sci J, 74, 541-548.

Heidarisafar, Z., G. Sadeghi, A. Karimi, and O. Azizi (2016). Apple peel waste as a natural antioxidant for heat-stressed broiler chickens. Trop Anim Health Prod, 48, 831-835.

Jiménez-Moreno, E., J. M. González-Alvarado, A. González-Serrano, R. Lázaro, and G. G. Mateos (2009). Effect of dietary fiber and fat on performance and digestive traits of broilers from one to twenty-one days of age1. Poult. Sci., 88, 2562-2574.

Langhout, D. J., J. B. Schutte, L. P. Van, J. Wiebenga, and S. Tamminga (1999). Effect of dietary high- and low-methylated citrus pectin on the activity of the ileal microflora and morphology of the small intestinal wall of broiler chicks. Br. Poult. Sci., 40, 340-347.

Maina, H. M., E. S. Heidi, and M. H. Shagal (2012). Analytical screening of nutritional and non-essential components in unripe and ripe fruits of banana (Musa sapientum). Intern. J. of Med. Plant Res., 1, 20-25.

Miura, D., Y. Miura, and K. Yagasaki (2007). Effect of Apple Polyphenol Extract on Hepatoma Proliferation and Invasion in Culture and on Tumor Growth, Metastasis, and Abnormal Lipoprotein Profiles in Hepatoma-Bearing Rats. Bio. Biotech and Biochem., *71*, 2743-2750.

Osada, K., T. Suzuki, Y. Kawakami, M. Senda, A. Kasai, M. Sami, and M. Ikeda (2006). Dose-dependent hypocholesterolemic actions of dietary apple polyphenol in rats fed cholesterol. Lipids, 41, 133-139.

Rizal, Y., M. E. Mahata, M. Andriani, and Wu, G. (2010). Utilization of Juice Wastes as Corn Replacement in the Broiler Diet. Int. J. Poult. Sci., 4, 8.

Rumsey, T. (1978). Ruminal fermentation products and plasma ammonia of fistulated steers fed apple pomace-urea diets. J. Anim. Sci., 47, 967-976.

Sanchez, R., F. Zamora, G. Buitrago, M. Ballesteros, L. Villamizar, and D. Anzola (2005). Use of Apple by-products in poultary rations of broiler chicks in Karachi. Pak J Physiol, 1, 1-2.

Silas, A. (2014). Effect of Stocking Density and Quantitative Feed Restriction on Growth Performance, Digestibility, Haematological Characteristics and Cost of Starting Broiler Chicks. J. Anim. Health Prod., 2, 60-64.

Svihus, B. (2011). The gizzard: function, influence of diet structure and effects on nutrient availability. Worlds Poult Sci J, 67, 207-224.

Tetens, I. (2012). EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA); Scientific Opinion on bovine lactoferrin. EFSA Journal, 10(8).

Thakur, B. R., Singh, R. K., and Handa, A. K. (1997). Chemistry and uses of pectin--a review. Crit Rev Food Sci Nutr, 37, 47-73.

Wolfe, K., X. Wu, and R. H. Liu (2003). Antioxidant activity of apple peels. J Agric Food Chem, 51, 609-614.