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# Productive performance and meat quality of commercial Cobb chicken fed diets containing different levels of prickly pear fruits (Opuntia ficus indica) peel

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## Abstract

**Background:** The objective of this study was to determine the impacts arising from the substitution of prickly pear fruits (Opuntia ficus indica) peels at different levels (0, 5, 10, and 15%) with yellow corn grain in broiler diets and meat quality. In this study, 200 male chick of commercial Cobb breed were used to study the effect of partially replacing of yellow corn grain (YC) with prickly pear fruits peel powder (PPP). Chicks were divided into four treatments (50 birds each), each treatment contained 5 replicates of 10 birds each. The experimental treatments were the following: 1—control diet (R1). 2—diet containing 5% pp (R2). 3—diet containing 10% pp (R3), and 4—diet containing 15% pp (R4). Feeding trails extending to 6 weeks.

**Results:** Obtained results illustrated that feed intake, live body weight, feed conversion ratio of broiler fed diet containing PPP were better ($P < 0.05$) than that of control. Broilers fed diet containing 5, 10, and 15% PPP were heavier ($P < 0.05$) by 1.60, 3.68, and 5.78%, respectively, over those fed the control diet. Inoculation of diets containing PPP achieved high ($P < 0.05$) carcasses weight and dressing% compared with control. Significant differences ($P < 0.05$) were detected for serum total protein, and total globulin of blood serum broiler as feeding inclusion levels of tested diets. Broiler fed diets contained 15% achieved higher degrees of taste, color, odor (aroma), texture, and overall acceptability. Highest ($P < 0.05$) biological value, true-digestibility and net protein utilization of broiler meat-fed PPP than other groups of control which was expected, as casein is a protein source with optimal digestibility.

**Conclusions:** It could be concluded that feeding commercial Cobb chicken on diets containing 15% prickly pear peel (Opuntia ficus indica) peel substituted with yellow corn grain, resulted in superior nutrition status and better daily gain, feed conversion ratio, economical efficiency, and better meat quality, as compared with other groups could be recommended.

**Keywords:** Prickly pear peel powder, Growth performance, Poultry, Sensory test, Protein quality of meat

## Introduction

In Egypt, there is a gap between the available and required poultry feed ingredients. Yellow corn grains and soybean meal production is not adequate to supply poultry feed and it depends on the use of imported these ingredients. So, the use of agro-industrial by-products and unconventional ingredients is widely spread minimizing the feed cost. Prickly pears (Opuntia spp.) have a fundamental economic importance in many desert areas, which are produced in abundant quantities (Ali 2001; EL-Nagmy et al. 2001; Ragab 2012). This is an interesting vegetable due to the environmental conditions in which it grows and its resistance to climatic extremes; however, little is known about its nutritional properties, especially in the later stages of maturity. The cactus-pear fruit is an oval, elongated berry, with a thick pericarp

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and a juicy pulp and, in general, many hard seeds. The pericarp of commercially ripe fruits of *Opuntia ficus-indica (L.)* accounts for 33% to 55% (Stintzing and Carle, 2005), while the pulp is 45 to 67%, the latter containing seeds (2 to 10%) Barbera et al. 1994 and Nieddu et al. 1997. The total cultivated area with prickly pear is about 2814 feddan produced 29610-ton fruits. (Ministry of Agriculture, 2005). Using prickly pear peel powder for poultry improved their performance and reduced the cost of feeding as it minimizes the amount of expensive yellow corn grain needed in poultry diets as the source of energy (Ragab 2012). The fruits of prickly pear peel have anti-inflammatory and analgesic effects (Park et al. 2001), anti-hyperglycemia and hypocholesterolemic effects (Roman-Ramos et al. 1995; Perfumi and Tacconi 1996). The neutral benefits of prickly pear fruits are believed to their antioxidant properties related to ascorbic acid, phenolics and a mixture of betaxanthin and betacyanin pigments (Butera et al., 2002; Tesoriere et al. 2003). Shedbalkar et al. (2010) found that the pulp of prickly pears contained phenolics and other antioxidants such as biothiol and concluded that they had a positive effect on the redox balance of humans mainly due to reduced LDL hydroperoxides levels. The nutraceutical benefits have been attributed to the synergistic effects of betalains and flavonoids (Stintzing et al. 2005). Recent investigations showed that the effectiveness of polysaccharides derived from Opuntia spp. as well as taurine against $H_2O_2$-induced damage, free radical-scavenging, antidiabetic, and blood lipid-lowering effects (Huang et al. 2008; Zhao et al. 2011). The most important aspect of poultry meat is its eating quality—a function of the combined effects of appearance, texture, and flavor. Poultry processing affects meat quality by establishing the chemistry of the muscle constituents and their interactions within the muscle structure. The producer, processor, retailer, and consumer all have specific expectations for the quality attributes of poultry; however, the ultimate authority will always be the consumer. However, rare studies have reported or assessed its replacement rates or comparative feeding value primarily with prickly pear peel powder or the rate of participation in poultry diets. The aim of this study was to evaluate the effects of presence of prickly cactus pear (Opuntia ficus-indica) fruit peel at rates of 0, 5, 10, and 15% with yellow corn grains in broiler diets, as well as the effect of its presence of cactus fruit peel on feed conversion ratio, meat quality, and its biological value.

## Material and methods

The experimental work of the present study was conducted at the Reference Laboratory for Poultry Production Control, while chemical analyses of ingredients, diets, and meat were performed in the Regional Center for Food and Feed, belonging to Agriculture, Research Center.

### Peels powder of prickly pears samples

The ripened cactus fruit was collected from the sellers and then spread on a clean floor for sun-drying at the solar unite National Research Center. After complete dryness, the material was ground using a mixer grinder and stored in plastic bags and preserved at − 20 °C until formulating the experimental diets (Table 1).

A total number of 200, 1-day-old commercial Cobb male chicks were used in this experiment and were initially fed a control diet (containing about 23% CP and 3001–3125 kcal ME/kg) for 42 days. Chicks were wing-banded and randomly allotted to the dietary treatments.

**Table 1** Composition and determined analysis of the experimental diets

| Item | Experimental diets | | | |
|---|---|---|---|---|
| | R1 | R2 | R3 | R4 |
| Ingredients: | | | | |
| Yellow corn grain | 61.00 | 54.95 | 54.90 | 51.85 |
| Soybean meal 47% | 29.50 | 29.50 | 29.50 | 29.50 |
| Prickly pear peels powder | 0 | 3.05 | 6.10 | 9.15 |
| Soybean oil | 3.30 | 3.30 | 3.30 | 3.30 |
| Corn gluten 60% | 2.00 | 2.00 | 2.00 | 2.00 |
| Dicalcium phosphate | 2.3 | 2.3 | 2.3 | 2.3 |
| Calcium carbonate | 0.40 | 0.40 | 0.40 | 0.40 |
| DL-methionine | 0.27 | 0.27 | 0.27 | 0.27 |
| L-lysine HCL | 0.25 | 0.25 | 0.25 | 0.25 |
| Premix* | 0.30 | 0.30 | 0.30 | 0.30 |
| Common salt | 0.30 | 0.30 | 0.30 | 0.30 |
| Sodium bicarbonate | 0.20 | 0.20 | 0.20 | 0.20 |
| Choline choloride | 0.10 | 0.10 | 0.10 | 0.10 |
| L-threonine, 98.5% | 0.08 | 0.08 | 0.08 | 0.08 |
| Anti-mycotoxins | 0.10 | 0.10 | 0.10 | 0.10 |
| Anti-coccidia | 0.05 | 0.05 | 0.05 | 0.05 |
| Probiotic | 0.01 | 0.01 | 0.01 | 0.01 |
| Chemical analysis, DM% | | | | |
| CP | 20.85 | 20.80 | 20.98 | 20.96 |
| CF | 2.39 | 2.56 | 2.81 | 2.92 |
| EE | 6.86 | 6.85 | 6.96 | 6.84 |
| NFE | 63.26 | 64.78 | 63.88 | 63.56 |
| Ash | 5.64 | 5.01 | 5.37 | 5.72 |
| ME, kcal\g | 3101 | 3064 | 3125 | 3001 |

*Each 3.0 kg of the vitamins and minerals premix manufactured by Agri-Vet Company, Egypt, and contains vit. A, 12,000,000 IU; vit. D3 2,000,000 IU; vit. E, 10 g; vit. K3, 2.0 g; vit. B1, 1.0 g; vit. B2, 5 g; vit. B6, 1.5 g; vit. B12, 10 mg; choline chloride, 250 g; biotin, 50 mg; folic acid, 1 g; nicotinic acid, 30 g; Ca pantothenate, 10 g; Zn, 50 g; Cu, 10 g; Fe, 30 g; Co, 100 mg; Se, 100 mg; I, 1 g; Mn, 60 g and anti-oxidant, 10 g, and complete to 3.0 kg by calcium carbonate

Mortality was recorded daily. Chicks were divided into four treatments (50 birds each), each treatment contained 5 replicates of 10 birds each. The experimental treatments were as follows: 1—fed a basal diet (R1). 2—diet containing 5% pp (R2). 3—diet containing 10% pp (R3), and 4—diet containing 15% pp (R4). During all the experiment which extending to 6 weeks, the birds received water and feed ad libitum. The experimental diets were supplemented with minerals and vitamin mixture and DL-methionine to cover the Cobb male chicks recommended requirements (Table 1). Birds were raised in electrically heated batteries with raised mesh wire floors and had free access to feed and water. Batteries were placed into a room provided with continuous light and fans for ventilation. The birds were reared under similar environmental conditions.

Birds were individually weighed at weekly intervals during the experimental period. At the same time, feed consumption was recorded and feed conversion ratio (FCR, g feed/g gain) and live body weight gain (LBWG) were calculated. Mortality was recorded daily (no mortality of birds were recorded during the study period). At the end of the growing period, individual blood samples were taken from 5 birds. Blood samples were centrifuged at 4000 rpm for 20 min. Serum was separated and stored at − 20 °C till the biochemical analysis. Commercial kits purchased from Biomerieus (Marcyi; Etoile 69260, Charbonnieres, Les Bains, France) were used for all colorimetric determinations.

### Slaughtering and carcass characteristics

Ten birds around the average live body weight of each treatment were slaughtered at the end of the experiment (42 days of age), Birds were individually weighed to the nearest gram, and slaughtered by severing the carotid artery and jugular veins (Islamic method).

Then carcass characteristics including carcass weight, dressing%, and total giblets% (gizzard, liver, heart, and spleen), as percentages of live body weight were recorded. After that, all breast and thigh samples (40 samples) were weighed and kept for 24 h at 4 °C and drying at the solar unit, National Research Center to complete the physical and chemical analysis of broiler meat.

### Histopathological investigation

The organs (liver, gizzard, kidney, and intestine) of chickens were excised immediately and thoroughly washed with ice-cold physiological saline then specimens from liver, kidney and pancreas tissues were fixed immediately in 10% neutral buffered formalin, dehydrated in ascending grades of alcohol, cleared in xylene and embedded in paraffin wax. Sections of 5 μm in thickness were prepared and stained with hematoxylin and eosin (Bancroft et al. 1996) and examined microscopically.

### Sensory panel and descriptive sensory evaluation

Samples of boneless thigh and breast of each bird were packed before keeping at − 20 °C for 60 days. The panel test was carried out to evaluate the main characteristics of broiler meat properties as taste, aroma, texture and overall acceptability. Samples were fried at sunflower oil individually in water without the addition of any flavor enhancers. In this test, 20 persons were served diced chicken samples with water in between to remove the remaining flavor. The panelists were requested to evaluate the cooked samples with four-digit code for taste, (odor) aroma, color, texture and overall acceptability on a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) as described by Lopez-Ferrer et al. (1999).

### Sensory evaluation

#### *Sample preparation*

After cooking as described above, external connective tissue was trimmed and 2.0-cm-wide strips were removed from the breast by cutting next to a template aligned parallel to the muscle fibers, and then cut into cubes of approximately 2.0 × 2.0 × 2.0 cm (Wattanachan et al., 2004). Each panelist received five cubes which were placed in capped 4 once Styrofoam cups labeled with 3-digit blinding codes.

#### *Sensory panel and descriptive sensory evaluation*

A descriptive sensory evaluation was conducted using a modification of the Sow and Grongnet (2010) method. The training panelists learned to identify the sensory attributes required for describing the appearance, flavor, and texture of chicken meat. References and scales were also developed during the training sessions.

### Chemical analysis

#### *Feeds*

Proximate chemical analysis of feeds, ingredients, and meat of carcasses was done according to A.O.A.C. (2005). Energy value was determined using the isoperibol bomb calorimeter (Parr 1261), while fiber was done with ANKOM AOCS 2000 fiber analyzer. Singleton et al. (1999) was used to determine total phenolic content using (CECIL CE 2041 spectrophotometer 2000 series from CECIL instruments, Cambridge, England). The total flavonoid content was determined using the Dowd method as adapted by Arvouet-Grand et al. (1994), absorption readings at 415 nm (CECIL CE 2041 spectrophotometer 2000 series). β-mannanase content was determined as described by Gevany et al. (2014) and Pinho et al., (2014) at UV-Visible spectrophotometer (398 nm), while phytase activity was determined at 820 nm, according to Han et al. (1999) method. Glucose, sucrose, and fructose were determined using high-performance liquid chromatography according to Glyad (2002).

### *Blood serum metabolites*

Serum total proteins (TP) were determined according to Henry 1964, albumin according to Doumas and Blggs 1972, urea according to Patton and Grouch (1977), cholesterol according to Watson (1960); glucose according to Neese (1982) method and triglycerides according to Bucolo and David (1973).

### *Biology experiment*

Biological value, true digestibility, and net protein utilization were determined according to (Eggum 1973) using 5-weeks-old male albino rats "rats weighing 75 g." The rats were individually housed in metabolic cages and maintained at 22–24 °C with relative humidity 45–55%. Water was provided ad libitum. The rats were weighed at the beginning of the experiments and divided into five groups so that the average weights of the groups differed by no more than + 0.5 g weighing was repeated at the end of the preliminary and balance period; access to feed and water was prevented 3 h before weighing. The experimental period lasted for nine days consisting of 4 days preliminary period and 5 days for the main experiment as described by Eggum (1973). The experiment was carried out using five groups of rats, five rats for each divided as follows: group (1) rats fed casein as protein source "control group"; group (2) rats fed on diet contained powder of chicken meat of zero prickly pear peel additives; group (3) rats fed diet contained chicken meat of 05% prickly pear peel powder additives; group (4) rats fed diet contained chicken meat of 10% prickly pear peel powder additives and finally, group (5) rats fed on diet contained chicken meat of 15% prickly pear peel powder additives. Each animal received 150 mg N and 10 g dry matter daily throughout the preliminary and balanced periods. The nitrogen content of the diets was adjusted by using the basal diet consisting of N-free mixture. The rats were housed in individual metabolite cages. During the balanced period, urine, and feces were collected in separate two flasks containing 5% H2SO4 increase of urine receiver. At the end of the experiment, the animals were weighed and killed with chloroform.

Any feed left in the feed container was also weighed. The collection of urine and feces from each rat was collected for 5 days. Feces were homogenized in a blender; urine was diluted to volume with distilled water, and nitrogen determined by the Kjeldahl method described in (AOAC 2005).

### *Blood serum metabolites*

Serum total proteins (TP) were determined according to Henry 1964, albumin according to Doumas and Blggs 1972, AST and ALT according to Hafkenscheid and Dijt (1979), cholesterol according to Watson (1960) and triglycerides according to Bucolo and David (1973), while glucose according to Ziegenhorn et al. (1977).

### *Statistical analysis*

The data for all traits were statistically analyzed according to Snedecor and Cochran, 1980 in one-way analysis of variance design using general linear model (GLM) procedure by computer program of SAS (2004) using the model:

Yijk= μ+Li+Ej+LEij+eijk Where

Yijk: observed value μ: overall mean

Li: level of diets containing ppp effect (i: 0, 5, and 15%)

eijk: random error

Treatment means indicating significant differences ( $P \leq 0.05$) were tested using Duncan's multiple range test (Duncan 1955).

## Results

### Chemical composition of prickly pears peel powder

Prickly pears peel powder contained, crude protein 9.60%, free fatty acids 0.63%, neutral detergent fiber (NDF) 60.12%, acid detergent fiber (ADF) 35.50%, calculated metabolizable energy 2850 kcal/g, total phenols (gallic acid equivalent), 8304 mg/100 g, flavonoids (Quercetin equivalent) 1044 mg/100 g, β-Mannanase, 1.2 μmol/g, phytase, 0.8 μmol/min, while carbohydrates values were glucose, 4.40%, sucrose, 1.88%, and fructose, 3.88% (Table 2). In this concept, these results were closed with (Stintzing et al. 2005).

### Growth performance

Effect of partially replacing yellow corn grain (YCG) with different levels of prickly pear peel powder (PPP) on live body weight (LBW), live body weight gain (LBWG), feed intake (FI), and feed conversion ratio (FCR) in growing commercial Cobb male chick diets are shown in Table 3. Level of YCG replacing effect was significant for LBW and LBWG during all the growth periods. However, the level of YCG replacing had an insignificant effect on LBW at 14 and the final body weight of commercial Cobb male chicks at 42 days of age and LBWG during the same period. Inclusion of PPP in commercial Cobb male chick diets at different levels caused a significant ($P < 0.05$) increase in LBWG during the total period, on the other hand, commercial Cobb male chicks fed diets containing 5, 10, or 15% PPP had higher LBWG values during these period. Performance of the growing broiler (Table 3) indicated that broilers fed diet containing 5, 10, and 15% PPP were heavier ($P < 0.05$) by 1.60, 3.68, and 5.78%, respectively, over those fed the control diet.

Concerning the FI values, significant differences were found due to level of PPP replacing during the periods of study 42 days, male chicks fed control diet (0.0%) PPP had lower FI during these periods, while, male chicks fed

**Table 2** Calculated nutrients composition and metabolic energy (ME*) of the main ingredients and the experimental rations

| Item | Yellow corn grains | Prickly pear peels |
|---|---|---|
| Organic matter | 88.57 | 87.64 |
| Crude protein | 7.85 | 9.60 |
| Free fatty acids, % | – | 0.63 |
| Ash | 1.43 | 12.40 |
| Neutral detergent fiber (NDF), % | 9.03 | 60.12 |
| Acid detergent fiber (ADF), % | 2.21 | 35.50 |
| *ME kcal/kg | 3350 | 2850 |
| Total phenols (gallic acid equivalent), mg/100 g | – | 8304 |
| Flavonoids (quercetin equivalent), mg/100 g | – | 1044 |
| β-mannanase, μmol/g | – | 1.20 |
| Phytase, μmol/min | – | 0.80 |
| Glucose, % | – | 4.40 |
| Sucrose, % | – | 1.88 |
| Fructose, % | – | 3.88 |

**ME*, calculated according to MAAF (1975) using equations being DE (MJ/kg DM) = digestible organic matter (DOM × 19) and ME (MJ/kg DM) = DE−0.82

partial replacing of PPP by 15% PPP had higher FI value during these periods. On the other hand, partial replacing of YCG by PPP enhanced FI during all the period compared with those fed the 5 and 10.0% PPP or control (Table 3). These increments in live body weight and body weight gain may be attributed to increasing digestion of all nutrients. Also, this may give an indication that the inclusion of PPP in commercial Cobb male chick diets did not have a negative effect on diet palatability or anti-nutritional factors (trypsin inhibitor).

Concerning the FCR values, significant differences were found due to levels of PPP replacing during the growth period, male chicks fed different levels of PPP-containing diets had the best FC, while male chicks fed control diet had the lowest FC value during these periods.

**Table 3** Productive of commercial Cobb broiler fed diets containing different levels of prickly peel

| Item | Levels of cactus fruit peel in diets | | | | +SE |
|---|---|---|---|---|---|
| | R1 (CR) (0%) | R2 (5%) | R3 (10%) | R4 (15%) | |
| Initial weight, g | 115 | 125 | 120 | 118 | 1.13 NS |
| Final weight, g | $1880^{d}$ | $1920^{c}$ | $1950^{b}$ | $1985^{a}$ | 2.76* |
| Total gain, g | $1765^{d}$ | $1795^{c}$ | $1830^{b}$ | $1867^{a}$ | 2.08* |
| Ave. feed consumption, g | $2859^{d}$ | $2746^{c}$ | $2763^{b}$ | $2801^{a}$ | 2.23* |
| Feed conversion ratio | $1.62^{b}$ | $1.53^{a}$ | $1.51^{a}$ | $1.50^{a}$ | 2.45* |
| Mortality rate, % | 0 | 0 | 0 | 0 | 0 |

+ a, b, c, dMeans with different superscripts on the same row are different at ($P < 0.05$), *NS* non-significant
*indicate present significance diffference

## Mortality rate, %

Data presented in (Table 3) showed no mortality in the growing broiler, it is worthy to note that no mortality was observed during the experimental period, meaning that the trypsin inhibitor activity concentration in prickly pear peels powder (antinutritional factor) is very low and no effect on the viability of broiler.

## Slaughter parameters

The slaughter parameters of chicks fed different levels of PPP are presented in Table 4. It is clear that partially replacing YCG with PPP levels affected slaughter parameters during all experimental periods (Table 4). Therefore, it may be concluded that PPP used in this study can substitute up to 15% of YCG at the experimental period without any detrimental effect on slaughter parameters and achieved high carcasses weight and dressing%. Carcass meat composition significantly influenced ($P < 0.05$) protein, fat, and ash%, front part had higher protein and ash%. However, PPP carcasses had higher crude protein content and lower fat than that of control, while the differences of ash% were insignificant.

## Clinical biochemistry

Significant differences ($P < 0.05$) were detected for plasma total protein and total globulin of blood serum broiler as feeding inclusion levels of tested diets (Table 5). However, the increase in total protein, albumin, and globulin was in a normal range as receiving 15% PPP may be associated with the improvement of crude protein digestibility. Liver function as AST and ALT activity were not affected by dietary treatments with

**Table 4** Carcass weight, dressing%, and chemical composition of commercial Cobb broiler fed diets containing different levels of prickly pear peel

| Item | Levels of prickly pear peel in diets | | | | +SE |
|---|---|---|---|---|---|
| | R1 (CR) (0%) | R2 (5%) | R3 (10%) | R4 (15%) | |
| Carcass weight, g | $1290^{d}$ | $1410^{c}$ | $1560^{a}$ | $1520^{b}$ | 3.28* |
| Dressing, % | $66.40^{c}$ | $68.91^{b}$ | $70.10^{a}$ | $70.00^{a}$ | 2.15* |
| Giblets, % | $4.23^{a}$ | $4.4^{a}$ | $4.5^{a}$ | $4.6^{a}$ | 0.16 NS |
| Chemical composition of meat (DM basis) | | | | | |
| Crude protein, % | 75.08b | 75.09b | 77.40a | 79. 09a | 1.12* |
| Ether extract, % | 15.88a | 15.37a | 12.59b | 11.50b | 1.02* |
| Ash, % | 9. 09a | 9.54a | 10.01a | 9.41a | 0.21 NS |

+, a, b, c, dMeans with different superscripts on the same row are different at ($P < 0.05$), NS: non-significant
*indicate present significance diffference

supplementing PPP. Values of AST and ALT were within the normal range and indicated that the animals were generally in a good nutritional status were determined as an indicator for enzymatic activity related to the rate of protein metabolism and liver function. It was evident that no significant variations were found for dietary treatments applied in liver functions. Also, levels of glucose, triglycerides, and cholesterols were significant differences ($P < 0.05$) and these levels were within the normal range.

### *Histopathological Investigation: the liver*

Macroscopically, the majority of chickens in groups fed formula with 5 (Fig. 1a) and 10% (Fig. 2a) prickly pear peels revealed normal liver, while group fed 15% (Fig. 3a) showed vacuolar degeneration and hepatocellular necrosis as compared with control.

### *The gizzard*

Most chickens did not show any changes in the gizzard. Chickens fed diets containing prickly pear peels revealed leucocytic infiltration in the mucosa and expansion of lamina propria by edema (Figs. 4 and 5).

### *The kidneys*

The majority of chicken groups fed on 5% (Figs. 6 and 7c) and 10% (Fig. 8c) prickly pear peels revealed slightly affected kidneys and chicken group fed diet containing 15% prickly pear peels (Fig. 8c) cactus peels showed moderate vascular and degenerative.

### *The intestine*

Chickens which fed diets containing prickly pear peels showed thickening in the wall of the small intestine with excessive mucus (Figs. 9 and 10d).

**Table 5** Effect of the experimental diets on some blood serum parameters of commercial Cobb broilers

| Item | Levels of cactus fruit peel in diets | | | | +SE |
|---|---|---|---|---|---|
| | R1 (CR) (0%) | R2 (5%) | R3 (10%) | R4 (15%) | |
| AST, IU/dl | 37.80 | 38.22 | 37.35 | 38.21 | 2.17 NS |
| ALT, IU/dl | 26.17 | 25.32 | 24.43 | 25.31 | 1.97 NS |
| T. Protein, g/dl | 3.44 c | 3.60 c | 3.53 b | 3.58a | 0.27* |
| Albumin, g/dl | 2.43 | 2.52 | 2.10 | 2.53 | 2.45 NS |
| Globulin, g/dl | 1.01b | $1.08^{b}$ | $1.73^{a}$ | $1.05^{a}$ | 1.48* |
| Glucose, mg/dl | 168.45 d | $178.32^{c}$ | $189.20^{b}$ | $194.08^{a}$ | 1.39* |
| Triglycerides, mg/dl | 1.02 a | $0.98^{b}$ | $0.96^{b}$ | $0.76^{c}$ | 0.17* |
| Cholesterol, mg/dl | 40.10a | $34.92^{b}$ | $31.40^{c}$ | $26.45^{d}$ | 2.36* |

+ a, b, c, d Means with different superscripts on the same row are different at ($P < 0.05$), *NS* non significant
*indicate present significance diffference

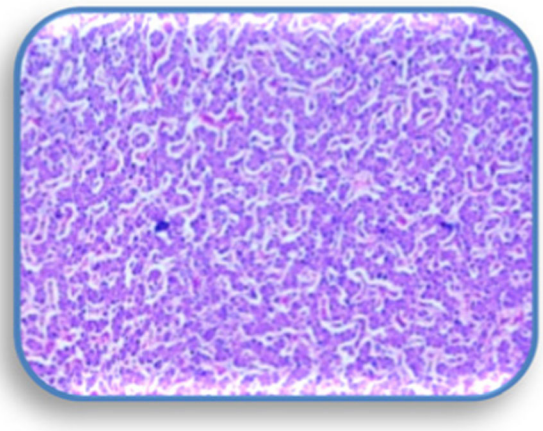

**Fig. 1** Liver control

## Sensory evaluation

### *Sensory evaluation of cooked meat*

Results detected in Table 6 show that there was a significant difference among prickly pear peel levels, where the groups of broiler fed diets contained 15% (R4) achieved higher degrees of taste, color, odor (aroma), texture, and overall acceptability.

Age of the bird at slaughter (young or mature birds) affects the flavor of the meat. Minor effects on meat flavor are related to bird strain, diet, environmental conditions (litter, ventilation, etc.), scalding temperatures, chilling, product packaging, and storage. However, these effects are too small for consumers to notice.

### *Biology experiment*

Data in Table 7 show that the R4 (15% PPP) presented the highest biological value, true digestibility and net protein utilization other groups control which was

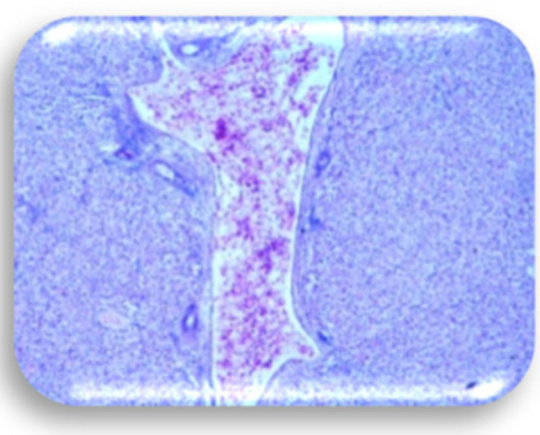

**Fig. 2** Liver of chicken fed on formula 5% and 10% cactus peels

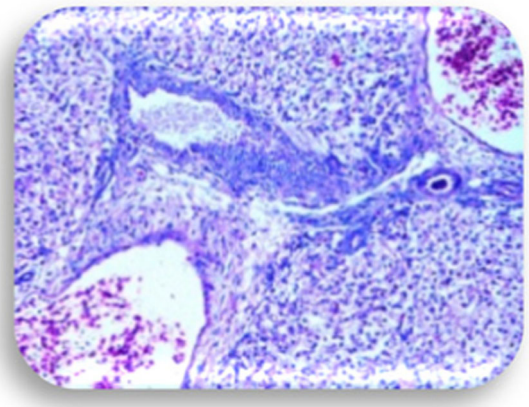

**Fig. 3** Liver of chicken fed on 15% cactus peels formula

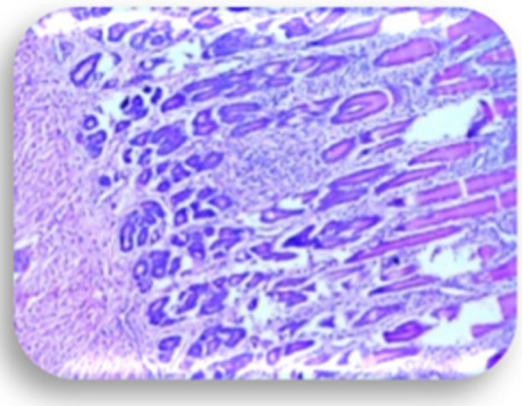

**Fig. 5** Gizzard of chicken fed on 5%, 10%, and 15% cactus formula

expected, as casein is a protein source with optimal digestibility. This was followed by R3, R2, and R1, respectively. However, no differences ($P > 0.05$) were detected between R2 and control casein groups. Differences ($P < 0.05$) between groups R1, R2, R3, and R4 were observed for true-digestibility (Table 7). Net protein utilization (NPU) relates weight gain to the amount of protein ingested during the experimental period; however, any variation in weight gain caused by other effects may generate some confusion as to the protein efficiency of the used diets.

Concerning meat quality, Babji et al. (1980) experimentally assessed the protein quality of mechanically separated meat of the of roasted chicken and the carcass of cooked chicken. The relative protein efficiency ratio of roasted and cooed chicken was 93.48% and 96.58%, respectively, which were slightly lower than that found meat in the present study.

Mean in vivo digestibility values were 84.88% and 83.28% for casein and 0% (free casein) of PPP chicken meat, respectively, and presented statistical difference ($P > 0.05$). According to Paleari et al. (1998), the digestibility of lean beef is 92%,

## Descriptive study

Results severity of the lesions of chicken fed different levels of prickly pears peels are shown in (Table 8). For birds fed 5% and 10% prickly pear peels formula, livers were slight enlarged and congested while group 15%, it revealed moderate enlargement and pallor discoloration. No changes in the gizzards of all birds of the experimental groups. Kidneys of birds fed 5% and 10% prickly pear peels revealed slightly affected, while that fed 15% containing prickly pear peels showed moderate severity of the lesions.

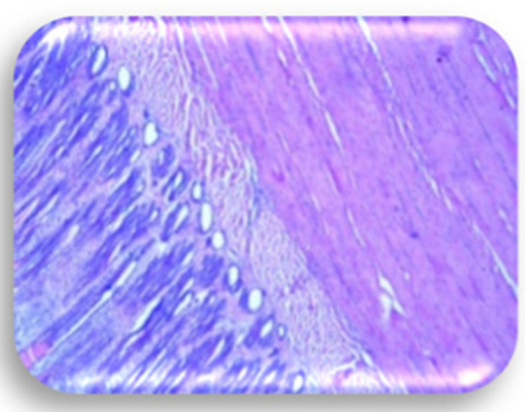

**Fig. 4** Gizzard control

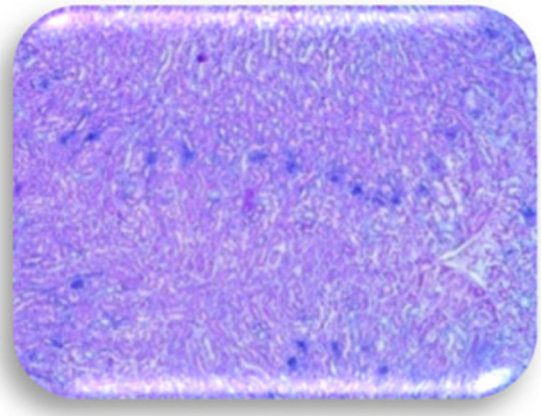

**Fig. 6** Kidney control

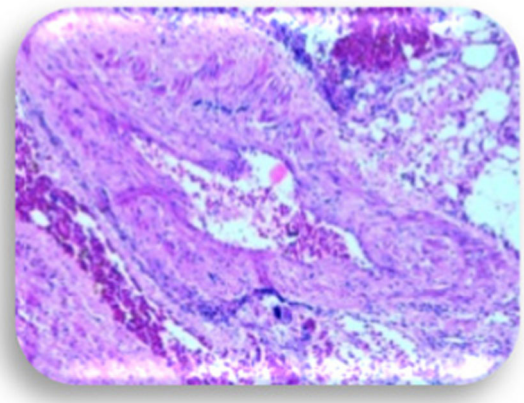

**Fig. 7** kidney of chicken fed on 5% and 10% cactus peels showing congested blood vessel and thickening of the wall and perivascular edema × 400

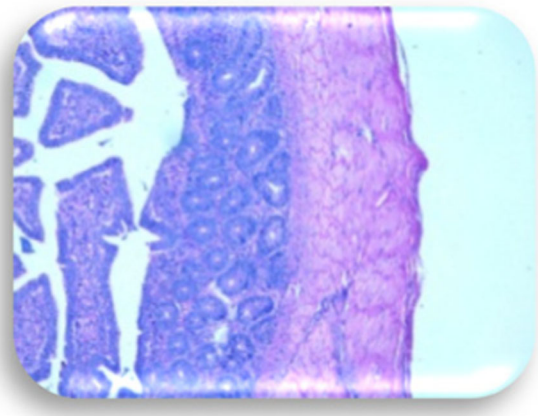

**Fig. 9** Intestine control

## Discussion

Growth performance results of birds fed diets containing PPP were that these agree with the findings of (Ali 2001) and El-Nagmy et al. 2001 who obtained positive results when fed growing quail diets containing 15 to 60% peels of prickly pear could successfully replace yellow corn. Also, El-kholy (1999) reported that yellow corn could be replaced successfully by 25% of either the fruit or the pulp of prickly pear and up to 75% using the peel of prickly pear without any adverse effect on the fish performance. The positive obtained results may be due to prickly pear have high dry matter digestibility (Gregory and Felker 1992) and also to be highly palatable to wild and domesticated rabbits (Hoffman et al. 1993; Ruiz-Feria et al. 1996). On the contrary, Ragab (2012) reported that no significant differences in LBW and LBWG of Hy- Line W-36 male chick diets. Bakr et al. (2017) reported that final weights of treated by oral dosage extract of peel prickly pear, rabbits were significantly ($P$ = 0.088) heavier by 20 g (2273 vs. 2253 g).

Regards to FI, Ruiz-Feria et al. (1998) mentioned that cactus prickly pear did not significantly influence any of the feed intake performance in control versus forage-fed pens depended on whether cactus was included in the diets ($P$ < 0.05). However, independent of the cactus effect, conversion of gross feed to total gains was improved in control (contained cactus prickly pear) versus forage-fed pens (P < 0.01). Rabbits fed 10% leucaena (with and without cactus) had higher pellet and gross feed intake levels ($P$ < 0.01),

The results of FCR obtained from this study differ from the results of El-Nagmy et al. (2001) and El-Kholy (1999) reported that FI was not affected due to replacing

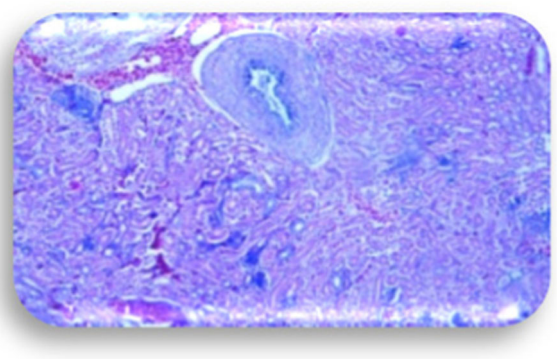

**Fig. 8** Vascular and degenerative changes, ×200 For chicken of groups fed 15% prickly pear peels

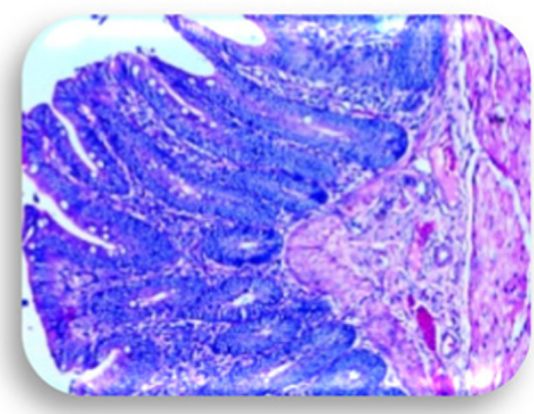

**Fig. 10** Activation of goblet cell and leukocytic infiltration in the mucosa and congested blood vessel for chicken group fed on 15% cactus peels

**Table 6** Effect of the experimental diets on sensory evaluation parameters of commercial Cobb broilers

| Item | Experimental diets | | | | + SE |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | |
| Taste | 7.35 c | 8.25 b | 8.80 b | 9.95a | 0.65* |
| Odor | 7.65 b | 8.30 a | 8.80 a | 8.95 a | 0.16* |
| Colour | 7.60 c | 8.20 b | 8.60 b | 9.80 a | 0.28* |
| Texture | 8.20 | 8.25 | 8.70 | 8.95 | 0.41* |
| Overall acceptability (palatability) | 7.70 c | 8.25 b | 8.68 b | 9.41a | 0.34* |

Point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) According to Lopez-Ferrer et al. (1999)

+, a, b, c, dMeans with different superscripts on the same row are different at ($P < 0.05$)

YCG by PPP in quail or fish diet. Other results cleared that, male broilers fed diets containing 30% PPP had the worst FC value (El-Nagmy et al. (2001) and Ragab (2012).

These results of mortality rate well harmony with finding of Bakr et al. (2017) who reported that, no mortality in rabbits treated by oral dosage extract of prickly pear peel powder. These encouraging results were obtained in this study, although no immunization or vaccination of birds.

Results of slaughter parameters are in harmony with those obtained by Ruiz-Feria et al. (1998) reported that rabbits fed 30% leucaena with cactus had 2.7% higher carcass weight ($P < 0.05$) and tended to have 1.0% higher pelt weight ($P < 0.10$) compared to those fed 30% leucaena without cactus. Zedan et al. (2015) who reported that inclusion of prickly pear cladodes (0, 10, 20, and 30%) significantly ($\underline{P} \leq 0.05$) increased dressing percentage and carcass weight of growing rabbits. On the other hand, Ragab (2007) reported that on Japanese quails and Ragab (2012) on Line W-36 male chick, reported that the level of PPP insignificantly affected slaughter parameters. In this respect, Ragab (2007) and Ragab (2012) show that the level of PPP insignificantly affected the chemical composition of broiler or quail meat.

Clinical biochemistry of blood parameters was in harmony with the finding of Zedan et al. (2015). Increasing globulin concentration with increased PP cladode inclusion which was observed in the present study may be an indication of increased immunity in the broilers since the liver will be able to synthesize enough globulins for immunologic action. This explains the decrease in mortality with increased PPP. Wolfram et al. (2002) reported that the ingestion of fresh cladodes reduced cholesterol concentration. It seems that the pectin of opuntia interferes with cholesterol biosynthesis and with its blood regulation. Louacini et al. (2012) showed that the pectin of opuntia tends to reduce cholesterol by binding to bile acids and the increases of their concentrations enhance the catabolism of cholesterol. Feugang et al. (2006) suggested that cactus pear reduces cholesterol levels in human blood and modify low-density lipoprotein (LDL). The antioxidant properties of the most frequent cactus pear betalains (betanin and indicaxanthin) have been revealed, anti-hyperglycemia and regulator of blood cholesterol (Tesoriere et al. 2004; Stintzing et al. 2005). Overall, the effects of cactus are generally attributed to the high fiber content of the cladodes, although other active ingredients (such as beta-carotene, vitamin E, and beta-sitosterol) may be involved. Also, treated with flavonoids, polyphenolic compounds, and certain alkaloids resulted to reduce cholesterol levels and play an important role in the prevention of a number of chronic diseases such as cancer and cardiovascular disease in rabbits. The decrease of cholesterol levels may be directly related to the influence of PPP on lipid metabolism. The protective effect of PPP upon some organs such as the liver and brain may be due to its contents of some flavonoids, such as quercerin and rutin, which play a role as an antioxidant against oxidative material which caused damage to such organs.

Results of the sensory evaluation are contrary to Bou et al. (2005) who found that consumer acceptability scores of cooked dark chicken meat after 74 days or after 18 months of frozen storage were not affected by energy source. This effect may be due to the ability of minerals of prickly pear peel which binds myoglobin and increase its oxygenation, thus facilitating the maintenance of meat color (Powell 2000). These results are in agreement with Bou et al. (2005) who found that consumer acceptability scores

**Table 7** Biological value, biological value, the tru-digestibility, and net protein utilization of commercial Cobb broiler meat-fed different levels of prickly pear peel powder

| Item | Control casein | Levels of prickly pear peel | | | | + SE |
|---|---|---|---|---|---|---|
| | | R1 (0%) | R2 (5%) | R3 (10%) | R4(15%) | |
| Biological value (BV) | 88.04$^{c}$ | 83.15$^{d}$ | 89.57$^{c}$ | 93.07$^{b}$ | 99.41$^{a}$ | 3.14* |
| Tru digestibility (TD) | 96.70 | 96.87 | 97.89 | 98.85 | 99.23 | 2.56 NS |
| Net protein utilization (NPU) | 84.88$^{c}$ | 83.28$^{c}$ | 85.80$^{c}$ | 95.36$^{b}$ | 98.76$^{a}$ | 2.84* |

+ a, b, c, dMeans with different superscripts on the same row are different at ($P < 0.05$), *NS* non-significant)

**Table 8** Severity of the lesions of chicken fed different levels of prickly pears peels

| Grops Organs | Chicken fed 0% prickly pears peels | Chicken fed 5% prickly pears peels | Chicken fed 10% prickly pears peels | Chicken fed on 15% prickly pears peels |
|---|---|---|---|---|
| Liver | + | + | + | ++ |
| Kidney | + | + | + | ++ |
| Intestine | – | – | – | + |
| Gizzaardl | – | – | – | + |

– no changes, + mild changes, ++ moderate changes

of cooked dark chicken meat after 74 day or after 18 months of frozen storage were not affected by dietary zinc sources or levels. Also, these results are inversely correlated with sensory scores (Mielche 1995; Bou et al. 2001). Liu et al. (2011) concluded that Supplemental Zn to broiler diets significantly increased the redness value in breast muscle.

Poultry meat color is affected by factors such as bird's age, sex, strain, diet, intramuscular fat, meat moisture content, pre-slaughter conditions, and processing variables. Color of meat depends upon the presence of the muscle pigments myoglobin and hemoglobin. Few factors during production and processing affect poultry meat flavor. This means that it is not only difficult to produce a flavor defect but it is difficult to enhance flavor during production and processing.

As regards to meat quality, Reis and Oliveira (2008) mentioned that although ostrich meat net protein ratio (NPR) value was lower than that determined for casein. Therefore, the parameter of net protein ratio (NPR) and in vivo digestibility are more reliable than PER to determine the protein quality of foods (Sarwar et al. 1989). A slightly lower value than that observed for chicken meat in the present study compared with ostrich meat, whereas Pires et al. (2006) reported 101.07% for beef. whereas other studies showed digestibility values of 88–89% (Hernandez et al. 1996), 90.3% (Abdel-Azis et al. 1997), and 98% (Schaafsma 2000).

## Conclusions

The overall results of this study showed beneficial effects of using prickly pear peel powder in broiler diets up to 15% substituted with yellow corn grain, where they could enhance the live body weight, feed conversion ratio, carcass traits, physical, chemical measurements of broiler meat, meat quality, and biological value of meat as well as increase the immunity without vaccine or drug which lead to low cost, also it considers binder agent and minimize the gain lost of feed. Further researches concerning using prickly pear peel in broiler diets and its safety to human consumption are needed

### Abbreviations

ADF: Acid detergent fiber; ALT: Alanine aminotransferase; AOAC (2005): Official method of analysis; AST: Aspartate aminotransferase; BV: Biological value; CP: Crude protein–crude fiber; EE: Ether extract; FCR: Feed conversion ratio; LBW: Live body weight; ME: Metabolizable energy; NDF: Nutrial detergent fiber; NFE: Nitrogen-free extract; NPU: Net protein utilization fil feed intake; PPP: Prickly pear powder; TD: Tru digestibility; YCG: Yellow corn grain

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### Authors' contributions

All authors wrote, read, and approved the final manuscript.

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### Availability of data and materials

The privilege of using and accessing morphological data used in this study is available to animal production Department: National Research Centre

### Ethics approval and consent to participate

All procedures and experimental protocols were conducted in accordance with the guide for the care and use of agricultural animals in research and teaching federation of animal sciences societies.

### Consent for publication

Applicable

### Competing interests

The authors declare that they have no competing interests.

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