Published in : Veterinarija ir Zootechnika (2023), vol. 81, n°1, pp. 1-9
Status : Postprint (Author's version)

EFFECT OF PARTIAL DIETARY SUBSTITUTION OF PRICKLY PEAR *(OPUNTIA FICUS INDICA L.)* SEEDS MEAL ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF BROILER CHICKEN

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KEYWORDS: prickly pear, seeds meal, weight carcass, growth performance, broiler chicken.

ABSTRACT

The objective of the present study was to investigate the effect of partial feed substitution with OFI meal on the growth performances and carcass characteristics of broiler chickens. One hundred and fifty 1-day-old broiler chicks (Arbor acres) were allocated into 5 groups with 3 replicates of 10 birds per group. The experimental groups received the diets substituted with 0 (control), 10% (B), 20% (C), 30% (D) and 40% (E) prickly pear seeds (PPS) meal of OFI during a 6-week duration divided into 4 dietary periods (starter diet, 0-12 days; grower diet, 13-33 days; finisher diet, 34-39 days; withdrawal diet, 40-45 days). At the end of the experiment, 5 birds from each sub-group were randomly selected and slaughtered, and the yield of the carcass segments was calculated. The growth performance of the broiler chickens seemed significantly affected ($P < 0.001$) by the PPS substitution level. The daily weight gain of the birds was exponential in the experimental groups. The results obtained indicate clearly that weight gain in the chickens fed treatments containing 10% PPS was significantly greater than in the chickens fed different treatments (20%, 30% and 40% PPS). Minimum feed intakes were observed in the birds with the diet substituted with 40% PPS. Feeding the birds with the substituted 10% PPS resulted in a significant increase ($P < 0.001$) in the weight of carcass and intestinal part at 45 days of age, when compared with the control group and the treated group. The results obtained under the conditions of this experiment showed that the partial dietary substitution of 10% PPS from Algeria can improve the growth performance and carcass yield in broiler chickens. Therefore, it is important to valorize the PPS by-product which would decrease the import invoice of animal feed, especially in broiler chickens.

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Status : Postprint (Author's version)

Introduction

Cacti are the most characteristic plants of the arid and semi-arid regions. *Opuntia ficus-indica* (OFI) L., commonly called prickly pear or nopal cactus, belongs to the dicotyledonous angiosper *Cactaceae* family, which includes about 1500 species of cactus. Also, cacti are known for their ability to thrive under environments recognized as stressful for most plant species, and are widely used to prevent soil erosion and to combat desertification (Scheinvar, 1995; Le Houerou, 2000). OFI has been exploited as a cheap and alternative source of food suitable not only for humans but also for animals. In addition, Cacti have been cultivated as ornamental crops to delimit lands (Estrada-Luna et al., 2008). Two parts of OFI are used for food, namely cladodes and prickly pears. Cladodes are consumed in Mexico as salads (Medina et al., 2007) whereas fruits are widely eaten fresh, dried or preserved (Medina et al., 2007). OFI fruits are fleshy and elongated berries, varying in shape, size and color and have a consistent number of hard seeds (Piga, 2004).

Opuntia gender is native of the Americas and has spread in many parts of the world including North Africa, the Mediterranean basin and the Middle East (El Mostafa et al., 2014). OFI is rich in phenolic compounds among other phytochemicals, and is widely used in folk medicine (Andreu et al., 2018). It is traditionally used for its antioxidant (Pes et al., 2016), anti-microbial (El Mostafa et al., 2014), antifungal (Ennouri et al., 2014), anti-inflammatory (Benayad et al., 2014), hypoglycaemic (Newman and al., 2016), or diuretic effects (Ammar et al., 2012). It helps preventing adipocyte hypertrophy and hepatic steatosis (Rodiguez-Rodriguez et al., 2015). The important biological activities of OFI are attributed to its different bioactive compounds such as gallic acid, catechin quercetin or resveratrol (Belviranli et al. 2019). Seeds of OFI often are considered as waste material during fruit processing but can be used to extract oil, due to its fatty acid composition.

In Algeria, poultry farming is an important sector of livestock production and contributes significantly to food security. However, feed costs affect negatively chicken production profitability. Therefore, the exploration of new feed resources and their effective use should be encouraged. In this country, OFI is a significant portion of the agricultural economy (150 000 hectares) (Boumaliet al., 2022), with huge production of fruits. According to the Direction of Agricultural Services, a large part of OFI is found in the northeast of Algeria and generates a huge quantity of residues. OFI by-products thus could be used in poultry feeding. To our knowledge, there are few studies on the effects of OFI seed meal on poultry performance under a different food matrix. Thus, the objective of the present study was to investigate the effect of partial feed substitution with OFI meal on the growth performances and carcass characteristics of broiler chickens.

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Materials and Methods

The experimental protocol was approved by the Scientific Faculty Council of the University of El-Tarf (Algeria) and the authors followed the regulations applied in University of Liege (Belgium).

STUDY AREA

This study was conducted from August to September 2018 in Beni-Mazline locality, Western Algeria (36°27'N, 7°25'E). The annual winter rainfall in the region ranges between 400 and 500 mm. The mean temperature and humidity during the experimental period reached 28°C (min 22.1°C and max 36.8°C) and 56%, respectively.

MEAL PRODUCTION AND CHEMICAL ANALYSIS

Prickly pear fruits were collected in March through April 2018 in El-Bourdj (Souk-Ahras province, Northern Algeria) (36° 17'N, 7° 57'E). The dry byproduct of OFI was obtained in a traditional mill immediately after the pressing operation of OFI fruits. The mixture is passed through a sieve with mesh for the separation of the seeds. After then, the seeds are washed, dried in the open air and sent to extract oil. The by-product was manually treated in order to reduce their size using a hammer, and then crushed using a traditional grinder. The final product was dark brown with a particle size of between 0.1 and 2 mm.

The chemical analysis was carried out according to the procedures of AOAC (2000). Dry matter content was determined from a test sample of 5 g in an oven at 105°C for 24 h (AFNOR, 1982). Crude protein (CP) was determined by the Kjeldahl method (AOAC, 955.04) (N x 6.25), and ether extract (EE) by the Soxhlet method (AOAC, 920.39). Crude fiber (CF) was determined by the Weende method (AOAC, 978.10). Finally, atomic absorption spectrometry was used to assay minerals, calcium (Ca), phosphorus (Ph), potassium (K), sodium (Na), magnesium (Mg).

ANIMALS AND DIETARY TREATMENTS

One hundred and fifty 1-day-old broiler chicks *(Arbor acres)* were obtained from a commercial hatchery. The birds were randomly allocated into 5 groups with 3 replicates of 10 birds per group and housed in pens of identical size (2x2 m) on a deep litter system with straw as floor. The birds from the control group (A) were fed, *ad libitum,* balanced commercial broiler diets for a 6-week duration divided into 4 dietary periods (starter diet, 0-12 days; grower diet, 13—33 days; finisher diet, 34-39 days; withdrawal diet, 40-45 days). The experimental groups received the same diets substituted with 10% (B), 20% (C), 30% (D) and 40% (E) of prickly pear seeds (PPS) meal of OFI. The chemical composition of the OFI prickly pear seed meal is shown in Table 1. The ingredients and the composition of the diets used in the experiment are presented in Table 2.

Birds were vaccinated against Gumboro (IBA-VAC®) and Newcastle (BIO-VAC® B1) diseases according to laboratory recommendations. In order to prevent coccidiosis, the chicks were treated

by anticoccidial at 15 and 28 days for 3 days (HIPRAVIAR®). They were reared for 6 weeks, maintaining all hygienic measures in a well-ventilated and temperature-controlled poultry house. Chicks were managed according to the guidelines suggested by Cobb Broiler Commercial Management Guide *(Arbos Acres* plus).

GROWTH PERFORMANCES AND CARCASS CHARACTERISTICS

All birds were weighed individually at the same time after their arrival from the hatchery to the experimental farm and every 7 days until slaughter. Feed intakes (FI) per pen, individual body weight gain (WG) and feed conversion ratio (FCR) were calculated per period. Daily weight gain (DWG; g/d) was calculated as weekly body weight gain/7. Overall FCR was also calculated from total Fl/overall WG. Mortality rate was recorded daily for each pen and calculated as a number of dead birds / total number of birds x 100.

At the end of the experiment, 5 birds from each sub-group were randomly selected and slaughtered. The slaughtered animals were plucked, eviscerated and weighed to calculate carcass weight including skin. The carcass was then dissected to characterize carcass segments. Carcass yield was calculated according to the ratio: eviscerated weight / live weight.

Statistical Analysis

The SAS® software (version 9.4, Institute Inc, Cary, NC, USA) was used for statistical analysis. The effects of diet, age and sex on feed intake, body weight gain and feed conversion ratio were evaluated by a mixed model. Statistical analysis was performed using the *t* test to compare between different groups. For repeated measurements on the same experimental unit, a similar model was used but including the effect of a compound symmetry covariance structure. Orthogonal polynomials were performed to determine the linear and quadratic effects of an increasing level of PPO in the diets. The data were expressed as mean **+/-** SE, and $P < 0.05$ was considered significant.

Results

The chemical and mineral composition of *Opuntia ficus-indica* L. powder flour prickly pear seeds are presented in Table 2. Metabolizable energy (ME, 2593 Kcal/kg), number of fiber bags fed (NDF, 35.9%), and acid detergent fiber (ADF, 30.5%) were calculated on dry matter basis. The prickly pear seeds (PPS) meal is composed of 95% of dry matter, 2% of ash, 9.8% of crude protein, 47.7% of crude fiber and 19% of ether extract. This powder also contained significant amounts of minerals (Ca, K, Mg, and Na) which have a high content of calcium (4.2 g/kg DM) and potassium (3 g/kg DM), while phosphorus, magnesium, and sodium occupy the second place with 2.4 g/kg, 0.3 g/kg, and 1.5 g/kg of dry matter, respectively.

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Initial and final body weights, average daily gain, mean daily consumption and consumption index during the different level treatments are shown in Table 3. The mortality rate of broilers did not exceed 1% during the period of the experiment in the treated and control groups. The growth performance of the broiler chickens seems to be significantly affected *(P* < 0.001) by the PPS substitution level. The daily weight gain of the birds was exponential in the experimental groups. The birds substituted with 10% PPS had a higher body weight (2939 g) than other groups substituted with 20%, 30% and 40% PPS (2622 g, 2527 g and 1745 g, respectively) during the experimental phases.

The average daily weight gain (from day 1 to 45) was higher for the control group than in chickens substituted with graded levels of 20%, 30% and 40% PPS.The results obtained indicate clearly that weight gain in the chickens fed treatments containing 10% PPS had a significantly greater weight gain than the chickens fed different treatments (20%, 30% and 40% PPS). Minimum feed intakes were observed in the birds with the diet substituted with 40% PPS, while the highest was noted in the chickens treated with 10% PPS. There is a significant difference between the control and the chickens fed different treatments *(P* < 0.05). Feed conversion rate (FCR) was low in birds supplemented with 30% PPS during the growth, finishing and withdrawal phases (1.58, 1.73 and 1.64, respectively) compared with other treatment groups.

The means of the weight of the carcass and the intestinal part for dietary treatments are shown in Table 4. Feeding birds with the substituted 10% PPS resulted in a significant increase *(P* < 0.001) in the weight of the carcass and the intestinal part at 45 days of age, when compared with the control group and the treated group (20%, 30% and 40% PPS).

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Table 1. *Formulas (kg/100 kg feed) of the phases of starter (1-12 days), grower (13-33 days), finisher (34-39 days), and withdrawal (40-45 days) feed distributed to broiler chickens.*

	Start-up phase (1-12 days)	Growth phase (13-33 days)	Finishing phase (34-39 days)	Withdrawal phase (40- 45days)
Ingredient composition				
Corn (%)	62.5	68	67.62	70
Oilcake of soy (%)	30	28	24	24
Milling issue (%)	3.5	1.3	5.38	4
Dicalcium phosphorus (%)	1.17	1	1	1
Limestone (%)	0.83	0.7	1	1
CMV DC (%)	P	P	-	-
CMV DL (%)	-	-	1	-
Antistress (%)	1	-	-	-
Analysis composition				
DM (%)	90.33	91.33	91.67	92
Crude protein (%)	17.9	29.9	20.4	19.1
Crude fiber (%)	3.8	3.5	3	2.9
Ash (% DM)	6.33	7	5	7
Raw ash (% Ash)	5.3	7	5.1	5.5
Insoluble ash (% Ash)	23.37	21.92	21.78	22.79
NDF (% DM)	43.39	34.35	40.45	35.63
ADF (% DM)	35.8	7.21	3.79	16.16
Ether extract (% DM)	22	16.67	19	13.33
Calcium (g/kg DM)	7.7	9.4	7.6	10.1
Phosphorus (g/kg DM)	6.1	7	5.6	7.1
Potassium (g/kg DM)	7.8	14.4	9.5	8.7
Sodium (g/kg DM)	2.1	2.8	0.9	0.1
Magnesium (g/kg DM)	2.2	2.4	1.7	1.8
Calculate composition				
Nitrogen (%)	2.86	4.78	3.26	3.06
EM (Kcal/kg)	2696	2774	2562	2057

DM: Dry matter; NDF: Number of fiber bags needed; ADF: Acid detergent fiber

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Table 2. *Chemical composition of prickly pear (Opuntia ficus indica L.) growing in Algeria*

Composition	Proportion
Chemical composition	
DM (%)	95
Crude protein (%)	9.8
Crude fiber(%)	47.7
Ash (% DM)	2
Raw ash (% ash)	4
Insoluble ash (% ash)	23.9
NDF (% DM)	35.9
ADF (% DM)	30.5
EE (% DM)	19
ME (Kcal/kg)	2119
Mimeral composition	
Calcium (g/kg DM)	4.2
Phosphorus (g/kg DM)	2.4
Potassium (g/kg DM)	3
Sodium (g/kg DM)	0.3
Magnesium (g/kg DM)	1.5
Nitrogen (%)	1.6

DM: Dry matter; NDF: Number of fiber bags needed; ADF: Acid detergent fiber; EE: Ether extract; ME: Metabolizable energy.

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Table 3. *Effect of graded levels of dietary substitution of prickly pear (Opuntia ficus indica L.) on the performance of broiler chickens*

	Substitution rate PPS (%)						
	0%	10%	20%	30%	40%	SEM	*P* value
Weight gain (g)							
1 day	44[a]	45[a]	45[a]	45[a]	45[a]	19.54	0.02
Start-up phase (1-12 days)	400[a]	395[a]	383[a]	340[b]	300[c]	19.54	0.02
Growth phase (13-33 days)	1900[a]	1908[a]	1800[b]	1593[c]	1312[d]	19.98	< 0.01
Finishing phase (34-39 days)	2502[b]	2600[a]	2200[c]	2000[d]	1500[e]	20.07	< 0.01
Withdrawal phase (40-45 days)	2825[b]	2939[a]	2622[c]	2527[d]	1745[e]	20.18	< 0.01
Daily weight gain (g/days/subject)							
Start-up phase (1-12 days)	33[a]	32[a]	30[a]	27[b]	25[b]	-	< 0.01
Growth phase (13-33 days)	79[a]	82[a]	76[a]	60[b]	51[c]	-	< 0.01
Finishing phase (34-39 days)	77[b]	87[a]	70[c]	69[c]	40[d]	-	< 0.01
Withdrawal phase (40-45 days)	36[b]	41[c]	51[b]	64[a]	27[c]	-	< 0.01
Intake feed (g/day/subject)							
Start-up phase (1-12 days)	397[b]	414[a]	381[c]	347[d]	329[e]	4.63	< 0.01
Growth phase (13-33 days)	2723[a]	2676[b]	2557[c]	2059[d]	1712[e]	4.70	< 0.01
Finishing phase (34-39 days)	984[a]	969[b]	934[c]	785[d]	589[e]	4.72	< 0.01
Withdrawal phase (40-45 days)	1051[a]	1057[a]	1021[b]	799[c]	648[d]	4.73	< 0.01
Feed conversion ratio							
Start-up phase (1-12 days)	1.23[a]	1.23[a]	1.22[a]	1.2[a]	1.16[b]	0.04	< 0.01
Growth phase (13-33 days)	1.69[a]	1.65[a]	1.68[a]	1.58[b]	1.58[b]	0.04	< 0.01
Finishing phase (34-39 days)	1.88[b]	1.75[c]	1.96[a]	1.73[c]	1.93[a]	0.04	< 0.01
Withdrawal phase (40-45 days)	2.13[a]	1.89[c]	1.91[b]	1.64[d]	1.94[b]	0.04	< 0.01

[a.b.c.d.e] A significant difference in parameters of growth performances between the control group (0% PPS) and the treated groups (10%, 20%, 30% and 40% PPS) is indicated by letters (P < 0.05). SEM = Standard error of the mean

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Table 4. *Effect of graded levels of dietary substitution of prickly pear (Opuntia ficus indica L.) on carcass part characteristics of broiler chickens*

Items	Substitution rate PPS (%)						
	0%	10%	20%	30%	40%	SEM	*P* value
Carcass weight							
G	2182^{b}	2271^{a}	1959^{c}	1912^{d}	1263^{e}	9.86	< 0.0001
%	73.27	73.51	73.17	74.48	71.31		
Head							
G	73^{a}	75^{a}	66^{b}	57^{c}	44^{d}	0.88	< 0.0001
%	2.4	2.4	2.5	2.2	2.5		
Paws							
G	92^{b}	103^{a}	95^{b}	78^{c}	71^{d}	1.87	< 0.0001
%	3.1	3.3	3.5	3	4		
Heart							
G	19^{b}	21^{a}	17^{c}	13^{d}	13^{d}	0.46	< 0.0001
%	0.6	0.7	0.6	0.5	0.7		
Liver weight							
G	58^{c}	63^{b}	56^{c}	66^{a}	47^{d}	1.1	< 0.0001
%	1.9	2	2.1	2.5	2.6		
Gizzard weight							
G	55^{b}	62^{a}	57^{b}	63^{a}	43^{c}	1.07	< 0.0001
%	1.8	1.9	2.1	2.4	2.4		
Proventriculus							
G	92^{b}	103^{a}	95^{a}	78^{c}	71^{d}	1.87	< 0.0001
%	3.1	3.3	3.5	3	4		
Intestine							
G	124^{b}	132^{a}	127^{b}	117^{c}	96^{d}	1.35	< 0.0001
%	4.2	4.3	4.7	4.6	5.4		
Thighs							
G	712^{a}	639^{c}	659^{b}	568^{d}	366^{e}	11.46	< 0.0001
%	32.63	28.13	33.63	29.70	28.87		
Wishbone							
G	520^{c}	545^{a}	530^{b}	412^{d}	284^{e}	9.65	< 0.0001
%	23.83	23.99	27.05	21.54	22.48		
Wings							
G	293^{b}	311^{a}	282^{c}	221^{d}	183^{e}	8.08	< 0.0001
%	13.42	13.69	14.39	11.55	14.48		

$^{a.b.c.d.e}$ A significant difference in carcass part characteristics between the control group (0% PPS) and the treated groups (10%, 20%, 30% and 40% PPS) is indicated by letters ($P < 0.05$). SEM = Standard error of the mean.

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Discussion

Several studies have reported that cactus pear is used as feed to supplement livestock diets, due to its main constituents, namely water (80-95%), followed by carbohydrates (3-7%), fiber (1-2%), and protein (0.5-1%) (Ginestra, et al., 2009; Bouzoubaa et al., 2016; Todaro et al., 2020). In the present study, the chemical analysis of a PPS cake revealed that moisture and dry matter content were 8.1% and 91.9 g/kg, respectively. The DM result is in agreement with the results previously described (Mokoboki & Sebola, 2017); however, Coşkuner and Tekin (2003) reported 71.5 g/kg of DM. According to the results of this study, the PPS contains 9.8 g/kg of crude proteins. Similar results (9.6%) have been described by Reda et al. (2020). Another investigation has demonstrated that a variety of *Opuntia,* which exhibited crude protein of 9.2%, is enough to enhance microbial growth (Mcitaka, 2008). Likewise, the study conducted by López-Cervantes et al. (2011) showed that the crude protein content of cactus pear cladodes flour was 7.24%. Meanwhile, Albergamo et al. (2022) have observed that *O. ficus-indica* seed had a higher protein content (17.34%). Our results also showed that the crude ash value was higher than those reported in previous investigation (Sawaya et al., 1983; Coşkuner & Tekin, 2003; Stintzing & Carle, 2005). These differences may be due to genetic factors, prickly pear varieties, cultivar or growth conditions, as well as geographical variations of prickly pear plants (De Wit et al., 2018). Moreover, variations in values between studies can be due to the stage of cactus maturity.

It is known that prickly pear is considered as a good source of minerals, namely potassium, magnesium, calcium and sodium (Chiteva & Wairagu, 2013; Ghazi et al., 2015; Albuquerque et al., 2016; El-Beltagi et al., 2019), although the site of culture and the physiological state of the vegetal tissue can influence the mineral content of OFI (Pastorelli et al., 2022). Our results showed different values of macro and microelements (Ca, Mg, K, and Na) and microelements (Fe, Mn, Cu, and Zn) in a PPS cake. The calcium content (4.2 g/kg) in PPS was similar to that obtained by Ghazi et al. (2015). However, Al- Juhaimi and Özcan (2012) have reported a low value of Ca and K ranging from 0.26 g/kg to 0.67 g/kg and 0.34 g/kg to 0.67 g/kg, respectively. In another investigation, Alsaad et al. (2019) have reported that the phosphorus content of a PPS cake was similar to those measured in our study. On the other hand, the phosphorus content was high in a PPS cake (2.4 g/kg) compared with those reported by Al-Juhaimi and Ozcan (2012) and Alves et al. (2017a), which varies between 1.17 g/kg and 1.87 g/kg; and 1.92 to 4.56 g/kg, respectively. However, Ghazi et al. (2015) have reported a high level of phosphorus (1417.59 mg / 100 g). Regarding the magnesium content, the value was similar (1.5 g/kg) to the results reported by Alsaad et al. (2019), and was high compared with the results reported by Al-Juhaimi and Ozcan (2012) (0.123 and 0.21 g/kg). These differences may be attributed necessarily to the harvesting season, soil properties, maturity degree or fruit processing, as well as to the equipment used (Benattia et al., 2019). Also, the variations in mineral content could be due to the age of the cladode (Alves et al., 2017b).

The incorporation of PPS in feed diet causes a very low mortality rate in the experimental groups. Nevertheless, the mortality rate remains acceptable as reported in livestock management. Ragab

(2007) have recorded a mortality rate of 3.3% in quails fed diets containing 15% PPP shells. However, Moula et al. (2019) have reported a mortality rate of 10% in broilers fed with 10% OFI cladodes in the diet. On other hand, several authors have reported that the incorporation of the by-product of OFI processing (husks, oilcake and zest) did not affect mortality in the experimental groups of chickens and rabbits (Bakr et al., 2017; Badr et al., 2019; Cherif et al., 2022). This difference in the mortality rates may be due to broiler strain genetics, individual fragility and stress factors as transportation.

In livestock production, nutrition represents an important factor to increase animal performance and, consequently, improve carcass traits and meat yield to be marketed. In arid and semi-arid regions, especially in Algeria, irregular availability of animal feed is the major problem faced by an animal production system. Many studies have been undertaken to develop alternatives in animal diet to reduce the import invoices, focusing on the potential use of natural feed additives. It is known that cactus is a plant that grows in adverse conditions, with little rainfall and poor soils (FAO, 2001). Despite the low nutritional quality of cactus forage, it remains interesting to investigate the OFI effect on the animal growth performance with other sources of protein or energy (Flores-Hernandez et al., 2019). The present experiment was to study the effects of a substitute of the PPS cake in the diet on the growth performances in chicken broilers at 42 days. These results are in agreement with results obtained recently, where the incorporation of OFI processing by-products into broiler feed at rates of 10% and 20% improves zootechnical performance (Cherif et al., 2022). According to the results of this study, the body weight gain average of chickens was significantly affected by a dietary 10% PPS substitution, *i.e.* by an average day gain of 59 g. This is consistent with the findings of Belghiti et al. (2021), who discovered that incorporation of the prickly pear cactus OFI fruit into the chicken broilers diet improved feed intake and weight gain. Moreover, Badret al. (2019) have concluded that feeding commercial chicken diets containing 15% prickly pear peel (PPP) substituted with corn grain resulted in a better daily gain and feed conversion ratio, as compared with other groups. Other studies have reported that the administration of PPP (15% to 60%) to quail showed a positive effect on the growth performance and could successfully replace yel-low corn in diet (Ali, 2001; El-Nagmy et al., 2001). On the other hand, Moula et al. (2019) have reported that chickens receiving OFI cladodes powder had numerically higher body weight and average daily gain than the controls, although not statistically significant. In another study, Ruiz-Feria et al. (1998) have reported that cactus prickly pear did not affect the feed intake when included in the diets versus the control group. Our results are in agreement with those reported by Gebremariam et al. (2006), where the body weight gain of growing lambs increased significantly with an increase of the cactus intake level. Nevertheless, Morshedy et al. (2020) have noted that the supplementation of 10 g of pear cactus seeds oil reduced the lamb weaning body weight compared with the control. Furthermore, Zedan et al. (2015) have reported that inclusion of prickly pear cladodes significantly increased the dressing percent-age and the carcass weight of growing rabbits. Meanwhile, other researchers have noted no significant difference among the treatment groups in lambs (Venkatesh et al., 2014; Ajith et al., 2017; Shashikumar 2017). The beneficial properties of *Opuntia* spp. are related also to their chemical content, such as polyphenols and flavonols that play an antioxidant capacity. However,

the content of phenolic compounds in OFI is affected by several variables, such as maturity stage, harvest season, environmental conditions and species. OFI of the PPS cake at different levels (10%, 20%, 30% and 40%) revealed a decrease significant difference, with a significantly low FCR in broiler chicken compared with the control group. This result is similar with that reported by Badr et al. (2019) and Pascoal et al. (2020). However, some research has noticed that male broilers fed diets containing 30% PPP had the wrong FC value (El-Nagmy et al., 2001; Ragab, 2012). Moreover, other studies have reported that FI was not affected when replacing yellow corn by pear pick in quail (El- Nagmy et al., 2001) or fish diet (El-Kholy, 1999). A growth performance increase in broiler chickens could be due to the stimulation of chaperone activity by a cactus product, thus reducing the deleterious effects caused by stress. In the literature, heat shock proteins, also known as molecular chaperones, consist of conserved molecules found in all organisms, because under stress conditions, such as heat, proteins tend to denature (Sung et al., 2011). It is noted that these controversial results might be attributed to high energy density and digestibility nature of cactus fruit meal (Tsega et al., 2016). As noted by Hoffman et al. (1993), the cactus cladodes in diet are very palatable to rabbits, due to the high sugar and low acid content (pH = 5.3-7.1). Likewise, it has been indicated that broiler chickens consume enough feed to satisfy their energy requirement (Giachetto et al., 2003). For this reason, high feed intakes were exhibited in the diets which contained higher levels of PPS compared with the control group.

In our results, we also found that the substitution rate of PPS resulted in significant differences in the weight of different carcass parts in broiler slaughter compared with the control group. Interestingly, these findings included a significant *(P*< 0.0001) increase in liver, gizzard, proventriculus and intestines weight. The same observation was noted for liver and gizzard weights in previous studies (Moula et al., 2019; Cherif et al., 2022). Because cactus contains secondary compounds (Bouaouich et al., 2023), it is highly likely that the degradation of the prickly pear seeds meal of OFI during digestion was high, resulting in high weight carcass. PPS oil is rich in unsaturated fatty acids such as linoleic acid and oleic acid. Among the saturated fatty acids, the most important are palmitic acid and stearic acid (Labuschagne & Hugo, 2010). It is known that the liver is the main site of lipid production, whereas the abdomen is the main site of fat storage. Badr et al. (2019) have reported that the carcass meat composition was significantly influenced *(P*< 0.05) with higher protein and fat percentage in chicks fed different levels of PPP. Besides, the weight intestines raised could be explained by an increased epithelial cell turnover due to feeding of microbial. Note that absorption and digestion capacity are essential to animal development that involves high villi and mature enterocytes (Cera et al., 1988). It has been noted that OFI intake is a good source of soluble fiber as pectin; insoluble fibers are cellulose and lignin (Bisson et al., 2010). As discussed in one review paper (Sacranie et al., 2012), the insoluble fiber diet has been shown to increase gizzard development. Likewise, Sacranie et al. (2012) have reported that the addition of hulls, rich in fiber, increased gizzard weight and content, but it had no effect on the ability of the birds to handle intermittent feeding.

Conclusion

The results obtained under the conditions of this experiment showed that the partial dietary substitution of 10% PPS from Algeria can improve the growth performance and the carcass yield in broiler chickens. The by-product prickly pear *(Opuntia ficus indica* L.) seeds are also a good source of energy and minerals; and they are rich in fibers and proteins. Therefore, it is important to valorize the PPS by-product which would decrease the import invoice of animal feed, especially in broiler chickens. Also, other approaches are necessary, such as the histology of intestines, to understand deeper the impact of PPS by-product on the intestine villi and the enterocytes.

FINANCIAL DISCLOSURE

This research received no grant from any funding agency/sector.

COMPETING INTERESTS

The authors declare that they have no potential conflict of interest.

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