

The By-Products of Prickly Pear Processing in Broiler Feed: Case of Dehydrated Husks and Cake

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Research

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Abstract

Background: The utilization of agro-industrial by-products is a potential substitution of imported raw materials in broiler feed formulas for developing countries. This study aims to determine the effects of substituting prickly pear husks for maize and prickly pear seed cake for soybean meal on the production performance, slaughter characteristics, and chemical composition of broiler meat.

Materials and methods: Two hundred day-old chicks of equal sex ratio (1:1) of Big Fast strain, weighing on average 37 ± 2 g, were randomly divided into 4 homogeneous groups of 50 subjects each. Each group was subdivided into 10 packs of 05 animals, banded and numbered. The rations distributed with a substitution rate of 0, 10%, 20%, and 30% of maize and soybean meal by dehydrated husks and prickly pear cake were randomly distributed through the different groups.

Results: Average daily gains and body weights at 48 days were improved ($p < 0.05$) for the 10% and 20% groups and the 30% group performed identically to the control. Cold carcass yield was optimal for 10% and 20% groups. The liver weight of the experimental groups decreased significantly ($p < 0.05$) while that of the gizzards increased significantly (+24 points). The meat protein rate evolved proportionally to the substitution rate, in contrast to the fat rate, which was depreciated by up to -1.08 points for the 30% group compared to the control.

Conclusion: The incorporation of prickly pear processing by-products into broiler feed at rates of 10% and 20% improves zootechnical performance, carcass yields, and the chemical composition of the meat.

Background

In Algeria, the costs of animal production are dependent on imports of the raw materials used in food formulae, thus generating meat products influenced by the parity of the Algerian dinar with foreign currencies. As pointed out by Guermah et al [1], the feeding of the domestic animal represents 70 % of the cost price of the products produced and remains under the influence of the prices posted by the world stock exchanges. The latter leads to inflation, making the prices of meat products beyond the reach of the poorest populations. The use of agricultural and agro-industrial by-products in domestic animal rations [2-7] is one way of regulating or even lowering the cost price of these products. The use of by-products from the processing of prickly pear (*Opuntia ficus-indica* L. mill) remains an alternative to be considered, given that this species is well represented in arid and semi-arid regions of the country (55,671 ha, [8]), is well adapted to a warm environment [9] and its fruits are used in local culinary customs and the cladodes consumed by the animals living there [10].

The prickly pear can be considered as a versatile crop [11] and as a substitute food due to its efficiency in converting water into the dry matter [12-15], thus ensuring a balance of digestible energy in pet food.

Prickly pear (FB) is eaten fresh [16], the pericarp accounts for 33% to 55%, the pulp for 45% to 67% and the seeds for 2% to 10% [17]. The fruit is also used for the production of juice, jellies, jams, vinegar, and oil from the seeds. This agro-industry generates by-products made up of husks, seeds, and oilcake, which are a source of environmental pollution because they are not valorized. According to **Kenny** [18], the yield per hectare is between 12 and 30 tones. If we consider that half of the planted area, i.e. 27836 ha for an average yield of 21T/ha of fruit, is taken care of by the agro-industry, the by-products generated in envelopes (pericarps) (44%) would be 257205T, in seeds (6%) of 35073T translatable into oilcake (97%) of 34021T. This total quantity of 291226T, is without context not negligible if it is valorized in animal feed.

The use of these by-products in poultry farming remains very little studied. **Moula et al** [19], in their study, used the whole fruit in Algeria in the same way as **Badr et al** [20] in Egypt, while **Regab** [21] experimented with the fruit envelope with the addition of enzymes.

For our part, our study aims to experiment with the by-products of the processing of Opuntia fruits (seed casings and cakes) in the diet of broilers.

Materials And Methods

The present study was conducted after approval of Institutional Animal Ethics Committee laboratory of Agriculture departement of Ghardaia University, Algeria.

Animals, diets, and experimental protocol

The trial was carried out at a poultry production unit in the municipality of El Kouif Wilaya of Tébessa (Algeria) in a building with a surface area of 80 m², fitted with thermal insulation made of polystyrene panels.

The study was carried out over a rearing period of 48 days, in a closed henhouse equipped with pad-cooling fans and humidifiers ensuring good ambient conditions. The litter consisted of sieved wood shavings.

Two hundred day-old chicks of equal sex ratio (1:1), of Big Fast strain, weighing on average 37±2g, were randomly divided into 4 homogeneous batches of 50 subjects each. Each batch was subdivided into 10 packs of 05 animals, banded and numbered, forming a control batch and three experimental batches.

The seed cakes and dehydrated prickly pear husks were supplied by an agro-industrial processing unit producing vinegar and prickly pear oil, located in the commune of Sidi fredj Wilaya of Souk-Ahras in south-eastern Algeria. The chemical composition of these two by-products is shown in **Table 1**.

Table 1. Chemical composition of prickly pear processing by-products in % DM		
	seed cake	Dehydrated envelopes
Dry matter (DM)	94,3	94,5
Organic matter	98.3	91.3
Total nitrogenous materials	8.8	5.6
Raw cellulose	55	52.3
Fats and fats	2.7	4
Mineral materials	1.7	8.7
Non-nitrogenous extractive	31,7	29,4
Gross energy (kcal/kg of DM)	4443	4166
Metabolizable energy (kcal/kg of DM) *	1818	1710
Lysine (g/100g protein)	0,54	0,98
Methionine (g/100g protein)	0,32	0 ,52
Cystine (g/100g protein)	0,31	0,62
* estimated according to the formula of Carpenter and Clegg (1956) with $ME (kcal/kg DM) = 35.3 \times CP (\%) + 79.5 \times F (\%) + 40.6 \times NNE (\%) + 199$		
<i>(ME : Metabolizable energy, CP : Crude protein, F: Fat, NNE: Non-nitrogenous extractive).</i>		

Using the WUFFDA software for broiler feed formulation, four rations were constituted, with 0% (control feed), 20%; 30%, and 40% substitution of soya meal by prickly pear seed cake and maize by their husks for the different rearing phases (**Table 2**). Rations were distributed randomly for the four broiler groups.

For the first ten days and thanks to gas-powered cattle raisers, a temperature varying between 36 and 38°C was maintained, as well as a 24-hour illumination, which was then reduced to 12 hours during the day and 6 hours at night.

Table 2. Formulas (kg/100 kg feed) of starter (1-20 days), grower (21-33 days), and finisher (34-48 days) feed distributed to chickens according to the rate of substitution of corn by prickly pear husks and soybean meal by prickly pear seed

	Start				Growth				Finishing			
	0	10	20	30	0	10	20	30	0	10	20	30
Substitution rate (%)	0	10	20	30	0	10	20	30	0	10	20	30
Ingredients												
Corn	61	55	49	43	64	58	51	45	70	63	56	49
Envelopes from FB	0	06	12	18	0	06	13	19	0	07	14	21
Soya cake	30	27	24	21	27	24	22	19	21	19	17	15
FB seed cake	0	03	06	09	0	3	5	08	0	02	4	06
From milling	6	6	6	6	6	6	6	6	6	6	6	6
Bi-calcium phosphorus	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
CMV	1,25	1,25	1,25	1,25	1	1	1	1	1	1	1	1
L-Lysine	0,15	0,15	0,15	0,15	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
DL-Methionine	0,4	0,4	0,4	0,4	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Nutrient content in % DM												
Metabolisable energy (Kcal/Kg of MS)	2890	2877	2847	2837	2840	2822	2812	2800	2990	3093	3120	3192
Crude protein (%)	21	18,2	20,3	20,4	20,3	19,1	19,1	19,1	18	17	17	16,5
Fat content (%)	2,8	5,4	5,2	5,0	2,9	3,2	5,1	4,9	3,0	5,0	4,9	4,7
Mineral materials (%)	3	3,5	3,8	4,09	2,7	3,4	3,7	4,1	2,9	3,2	3,6	4
Raw cellulose (%)	3,0	8,7	13,7	17,7	2,9	8,6	13,6	17,5	2,8	8,4	12,8	17,3
Lysine (%)	1,20	9,62	8,66	7,92	1,38	8,82	8,12	7,16	1,22	7,5	6,81	6,11
Methionine (%)	0,72	2,78	2,53	2,27	0,60	2,68	2,44	2,18	0,57	2,38	2,24	2,02

Water and feed were distributed ad-libitum and the refusal was weighed daily. Vaccination against Newcastle disease and infectious bronchitis was carried out at the 7th and 21st breeding farms and against Gumboro disease at 14 days of age (no booster vaccination). An anticoccidial was administered at 17 and 34 days of age for two successive days in drinking water. The animals were individually weighed at placement, 10; 20; 33, and 48 days of age. Mortality was recorded daily throughout the entire experiment.

At the end of the rearing, 30 chickens taken at random from each batch were sacrificed. The live weight, the weight of the warm and cold carcass, legs, head, feathers, gizzard, viscera, and liver were weighed. The average daily gain (ADG), average daily intake (ADI), and feed and liver were weighed. The average daily gain (ADG), average daily intake (ADI), and feed conversion ratio (FCR) were calculated. At 24 hours *post-mortem*, the pH was measured by direct insertion (~ 2 cm deep) of the electrode of a pH meter into the pectoral muscle of quails according to the method of **EL Rammouz**, [23]. Ash, protein, and fat content were determined and calculated according to **the Aoac** methods [24].

Statistical analysis

Descriptive statistics and single-factor analysis of variance (ANOVA) were performed with the SPSS software (version 18, 2008) for the analysis of performance, slaughter parameters, and meat chemical composition. The post hoc test by the application of the S.N.K (Student- Newman- Keules) and Duncan test, to estimate the significance or homogeneity between the different subsets (test of comparison between the means). The differences were considered significant with a 5% risk of error.

Results

No mortality was recorded during the whole breeding in all groups. During the start-up phase, the 10% group recorded significantly ($p < 0.05$) higher weights at 10 days and 20 days than the other groups with +24g and +51g respectively (**Table 3**).

Table 3. Changes in weight growth and ADG(g/d/subject) during the start-up, growth, and finishing phases as a function of substitution rates.						
	0	10	20	30	SEM	p
Start-up phase						
Initial weight (g)	37	37	37	37		
Weight at 10d (g)	137 ^b	161 ^a	114 ^d	128 ^c	2.19	0.001
ADG 1-10 (g/d/subject)	11,1 ^b	13,8 ^a	8,6 ^d	10,1 ^c	0.25	0.02
Weight at 20d (g)	438 ^b	489 ^a	412 ^c	407 ^c	9,67	0.01
ADG 11-20(g/d/subject)	33,4 ^b	36,4 ^a	33,1 ^b	31,0 ^b	1,13	0,001
ADG 1-20 (g/d/subject)	21,1 ^b	23,8 ^a	19,8 ^c	19,5 ^c	0.36	0.01
Growth phase						
Weight at 33 d (g)	1032 ^b	1139 ^a	1020 ^b	987 ^b	22,21	0.03
ADG 21-33 (g/d/subject)	49,5 ^b	54,2 ^a	50,6 ^b	48,3 ^b	1.48	0.015
Finishing phase						
Weight at 48 days (g)	2003 ^b	2225 ^a	2061 ^{ab}	1948 ^b	41.43	0.02
ADG 34-48 (g/d/subject)	69,49 ^b	77,5 ^a	74,3 ^{ab}	68,7 ^b	1.18	0.026
ADG 1-48 (g/d/subject)	39,7 ^b	43,9 ^a	41,4 ^{ab}	38,7 ^b	0.88	0.001
<i>The indices indicate the period in days over which this parameter was calculated. The presence of different letters on the same line indicates a significant difference between diets (P < 0.05).</i>						

The same trend was recorded for the ADG 1-10d (+2.7 g/d/subject) and the ADG 11-20d (+3 g/d/subject) respectively, as well as for the ADG 1-20d which, during the whole start-up phase, showed a significant difference ($p < 0.05$) of +2.7 g/d/subject with the control and +4.2 g/d/subject with the other experimental groups.

During the growth phase, the 10% substitution rate of soybean meal and maize impregnated a significant optimization ($p < 0.05$) of the weight at 33 days as well as of the ADG 21-33d with a difference of +126g and +8.7g/d/subject respectively compared to the average of the other batches. The latter being significantly similar.

In the finishing phase, the 30% batch took a minimum value ($p < 0.05$) in live weight at 48 days and ADG 34-48d compared to the other batches, the 20% batch recorded higher results than the control batch while the 10% batch with 2225g remained significantly dominant ($p < 0.05$), displaying an optimal ADG 34-48d of 77.5g/d/subject. The ADG 1-48d of the 10% and 20% batches showed a higher value than the control batch, while the result of the 30% batch was identical to the control batch.

The average daily intakes of the experimental batches showed less significant results

compared to the control lot during the first ten days with a difference of -5 points (**Table 4**).

Table 4. Changes in average daily intake and the consumption index as a function of the substitution rate						
	0	10	20	30	SEM	p
<i>Average daily intake</i> (g/subject)						
From 1 to 10 days	270 ^a	265 ^b	263 ^b	263 ^b	3,51	0,01
From 11 to 20 days	511 ^a	513 ^a	504 ^b	510 ^a	6.82	0.01
From 21 to 33 days	1500	1490	1488	1487	10.24	0.3
From 34 to 48 days	2844 ^b	2869 ^a	2870 ^a	2846 ^b	19.56	0.01
From 1 to 48 days	5125 ^b	5137 ^a	5125 ^b	5106 ^c	53.8	0.02
<i>Consumption index</i> (g/g)						
From 1 to 10 days	2.7 ^b	2.1 ^c	3.4 ^a	2.9 ^b	0,253	0,001
From 11 to 20 days	1.7 ^b	1.6 ^b	1.7 ^b	1.9 ^a	0.566	0.01
From 21 to 33 days	2.5	2.3	2.4	2.5	0.292	0.381
From 34 to 48 days	2.9 ^a	2.6 ^b	2.7 ^b	2.9 ^a	0.127	0.040
From 1 to 48 days	2,6 ^a	2,3 ^b	2,4 ^b	2,6 ^a	0.132	0.010
<i>The presence of different letters on the same line indicates a significant difference between the diets (P < 0.05).</i>						

Between day 11 and day 20, the substitution of soybean meal and maize produced a depreciation of the group's average daily intake of 20% of -10g compared to the other groups that showed similar results. It can also be noted that during the 34 -48 days interval, the 10% and 20% groups showed identical and superior results to the control groups and 30%, which took a mean value of 2845g impregnating a mean difference of -24g with respect to the witness. The entire farm was characterized by the influence of the substitution of soy and maize meal by prickly pear seed cake and their envelopes on the 10% group, giving it optimization of the average daily intake, a devaluation of this parameter for the 30% group and an intermediate and identical result for the 20% and control groups.

Between the 34th and 48th day and from the 1st to the 48th day, the consumption indices of the 10% and 20% groups of substitution of soybean meal by seed cake and maize meal by prickly pear husks were significantly similar and the least expressive (p<0.05) compared to the control groups and 30%.

The incorporation of prickly pear seed cake and husks in the broiler diet does not affect the weight of the viscera, head, legs, and feathers (**Table 5**).

Table 5. Changes in slaughter parameters and meat chemistry as a function of the substitution rate						
	0	10	20	30	SEM	p
Slaughter parameters						
Live weight(g) (Pv)	2009 ^b	2221 ^a	2052 ^{ab}	1990 ^b	119,1	0,019
Hot carcass weight (g)	1406 ^c	1597 ^a	1487 ^b	1398 ^c	41,38	0,019
Hot carcass yield %	69,9 ^b	72,0 ^a	72,5 ^a	70,2 ^b	0,12	0,011
Cold carcass weight (g)	1265 ^c	1494 ^a	1391 ^b	1222 ^d	44,1	0,01
Cold carcass yield%.	63 ^b	67,3 ^a	67,8 ^a	61,4 ^c	1,87	0,01
Visceral weight(g)	239	236	235	240	4,1	0,88
Head weight(g)	67	66	68	69	7,84	0,255
Leg weight(g)	100	98	110	100	11,63	0,353
Weight Feather (g)	147	146	146	147	11,03	0,817
Weight liver(g) (Pf)	53 ^a	47 ^b	45 ^b	46 ^b	7,82	0,034
Pf/Pv ratio (%)	2,6 ^a	2,1 ^b	2,2 ^b	2,3 ^b	0,56	0,014
Gizzard weight(g) (Pg)	58 ^b	85 ^a	82 ^a	80 ^a	11,06	0,029
Pg/Pv ratio (%)	2,9 ^b	3,8 ^a	3,9 ^a	4,0 ^a	0,87	0,021
Chemical composition of the meat						
pH	6,34 ^a	6,31 ^a	6,36 ^a	6,23 ^b	0,034	0,01
Crude protein content	16,36 ^b	18,39 ^a	18,50 ^a	18,77 ^a	0,61	0,004
Fat content	3,06 ^a	2,87 ^{ab}	2,56 ^b	1,98 ^c	0,183	0,001
Mineral content	0,88	0,98	0,92	0,94	0,148	0,267
<i>The presence of different letters on the same line indicates a significant difference between the diets (P < 0.05).</i>						

The hot carcass weights and yields of the 10% and 20% groups had optimal values ($p < 0.05$) compared to the control and the 30% group, which showed similar results ($p < 0.05$). The weights of cold carcasses were significantly different ($p < 0.05$) between all the groups with the supremacy of the 10% group inducing significantly similar yields ($p < 0.05$) and optimal for the 10% and 20% groups with a difference of about +4 points with the control. The 30% group recorded a minimum value.

The incorporation of FB seed cake and dehydrated husks resulted in a significant ($p < 0.05$) decrease in liver weight of the experimental groups with a similar mean value of 46.5g, resulting in a difference of -6.5g with respect to the control. The same observation was noted for the Pf/Pv ratios. On the other hand, the gizzard weights had an optimal and similar value for the experimental batches (average 82.3g), resulting in a significant difference ($p < 0.05$) of

+24.3g with respect to the control for Pg/Pv ratios expressing the same trend.

The pH of the meat at 24 hours post mortem, for the 10% and 20% groups were not influenced by the substitutions, which took on the same value with respect to the control, while the 30% group recorded a minimal result with respect to all the other groups. The experimental groups took significantly similar ($p < 0.05$) and maximum protein values, imparting a significant difference of +2.19g compared to the control. The mineral matter content was not influenced by the incorporation of FB seed cake and seed envelopes.

Discussion

The incorporation of the by-product of prickly pear processing (husks) and the by-product of oil extraction from BF seeds (oilcake) did not cause mortality in the experimental groups as reported by **Badr et al** [20] in Cobb chickens fed BF husks and **Bakr et al** [25] in rabbits fed BF zest. However, **Moula et al** [19], on broilers fed with 10% prickly pear cladodes in the diet, found a mortality rate of 10%, while **Ragab** [21] found a mortality rate of 3.3% in quails fed on diets containing 15% prickly pear shells.

The incorporation of FB fig seed husks and seed cakes at a rate of 10% and 20% in the feed of broiler chickens has led to an increase in live weight and ADG. This is in line with the results found by **Badr et al** [20], who found an improvement in weight performance due to the substitution of maize by FB envelopes of 5-15% in Cobb broilers. However, **Moula et al** [19] for a 5% and 10% incorporation of FB cladodes in the broiler feed, observed no significant effect on body weight and ADG, in contrast to **Ragab** [26] who found in Hy-Line W-36 cocks fed with FB envelopes, a non-significant effect on body weight at 70 days but a positive effect on ADG. As in quails, **Ragab** [21] found that the incorporation of 15% and 30% FB envelopes had no influence on body weight and ADG, while in rabbits, **Hassan et al** [27] reported final weights and ADG with a ration containing 25% and 50% FB envelopes, These results contradict those reported by **El-Neney et al** [28] who found that a 20% and 30% incorporation of FB envelopes resulted in a significant increase in live weight. In fattening sheep, **Islam et al**[29] and **Aware et al** [30] reported a positive effect on body weight with incorporation rates of 60% and 80%. Throughout the rearing period, the substitution of maize and soybean meal by prickly pear husks and meals respectively had a significant effect on average daily intake and feed conversion of broilers for the 10% and 20% groups. For their part, **Badr et al** [20] observed in Cobb chickens fed rations containing 5%, 10% and 15% FB envelopes, average daily intakes, and lower consumption indices than for the control, as did **El-Neney et al** [28] for the incorporation of FB envelopes and **Zeedan et al** [31] for the incorporation of FB cladodes, and in rabbits at levels of 10%, 20%, and 30%.

The incorporation of prickly pear husks and cakes at a rate of 10% and 20% in the feed for broilers has led to an increase in the weight of hot and cold carcasses, and livers and gizzards but had no significant effect on other slaughter parameters, in contrast to the findings of **Regab**[26] in male chicks of line W-36 and **Regab** [21] in quails, which recorded no influence of the incorporation of FB envelopes on the slaughter parameters. However, **Badr et al** [20] found that at an incorporation rate of 5%, 10%, and 15%), a significant influence on carcass and offal weights was observed. In rabbits, **Abu Shammalah** [32] found that the use of FB envelopes in rabbit rations influences carcass characteristics. The crude protein content of the meat increased while the fat content decreased, in proportion to the rates of incorporation of BF envelopes in the rabbit ration, in line with the results reported by **El-Neney et al** [28] and **Zeedan et al** [31]. These results remain in contradiction with those of **Regab** [21,26] and **Moula et al** [19].

Conclusion

The incorporation of prickly pear husks and cakes in the feed of broiler chickens at rates of 10% and 20% improves zootechnical performance, carcass yields, and the chemical composition of the meat.

Declarations

Acknowledgements

Not applicable.

Authors' contributions

IC prepared the ground conditions and collected the data. RA revised the manuscript. YA performed the analysis of the data. AM prepared the diets and the chemical analyses. FA designed the study and drafted. All authors have read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval

The present study was conducted after approval of Institutional Animal Ethics Committee laboratory of Agriculture departement of Ghardaia University, Algeria.

Availability of data and materials

The datasets analyzed in the present study are available from the corresponding author on reasonable request.

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