

Evaluation of the effect of nopal meal on meat quality of Japanese quails (*Coturnix japonica*)

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ABSTRACT

Objective: to evaluate the effect of supplementation, with nopal meal in the diet of Japanese quails, on the slaughter variables and quality properties of meat.

Design/Methodology/Approach: 200 female quails (49 d) were used that were randomly assigned to four treatments with five replicates (10 birds per experimental unit). The T1 treatment was the control diet, while the T2, T3 and T4 included different doses of nopal meal in miligrams per kilogram of feed (400, 800 and 1200 mg kg⁻¹).

Results: in the quails evaluated, nopal meal did not modify ($p > 0.05$) the weight at slaughter, yield or weights of non-chilled and chilled carcasses. Likewise, the weight of organs ($p > 0.05$) was not affected, but the length of the gizzard was modified ($p \leq 0.05$) with the addition of flour. Nonetheless, nopal meal did not influence the weights, both of the chilled and post-cooked legs ($p > 0.05$), nor the yield or texture of quail meat. However, the pH decreased, which improved luminosity ($p < 0.05$), and increased the intensity of red color, while the intensity of yellow decreased. In addition, water retention capacity was higher in meat of those quails supplemented with 400 mg kg⁻¹ of nopal flour in their feed.

Limitations/Implications of the study: according to our results it seems that, with higher concentrations of nopal meal, yields could also be higher. This modification is suggested for further research.

Findings/Conclusions: nopal meal did not influence the weight of the chilled legs, the cooking yield or meat texture. However, it is an additive that lowered the pH of quail meat; thus, it increased the luminosity and accentuated red color in meat, while decreasing the yellow pigments.

Palabras clave: antimicrobials, luminosity, pH, water holding capacity, carcass yield.

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INTRODUCTION

Poultry meat is a high-quality protein source characterized by high digestibility and complete essential amino acid profile. In addition, this meat contains lipids, vitamins and



minerals that are essential for balanced nutrition. In Mexico, chicken meat is the most consumed animal protein, representing 34.2% of total national consumption (Estévez & Miranda, 2022). However, quail is becoming an important animal, due to several advantages among which are rapid growth rate, high feed efficiency and the reduced space needed for rearing (Adom *et al.*, 2023).

Nowadays consumers are increasingly attentive to the quality of the food they consume, especially in regard to meat. Nutrition, environmental conditions and animal health play a crucial role in the final quality of the meat. This quality is evaluated by physicochemical characteristics such as pH, color, texture, water retention, drip water loss, appearance, and sensory properties (Bautista *et al.*, 2016). In this sense, poultry farming has resorted to the use of antimicrobials over time; however, knowledge about the potential risk to human health has led the poultry industry to look for natural alternatives to improve the yield, health and quality of meat in poultry (Abd El-Hack *et al.*, 2022).

Nutraceutical foods are known to modify and maintain normal physiological functions, thus contributing to the health of poultry individuals (Alagawany *et al.*, 2021). Among these food components is the prickly-pear plant (*Opuntia ficus-indica*), called nopal in Mexico, which contains phytochemicals such as terpenoids, phenolics, alkaloids and dietary fiber, with antioxidant capacity, which protects tissues from the damaging effect of free radicals (Aruwa *et al.*, 2018). In quail farming, information on the impact of nopal flour on meat quality in quails is not yet available. Therefore, the objective of this research was to evaluate the supplementation with nopal flour as an additive in feed on carcass yield and meat quality of Japanese quails.

MATERIALS AND METHODS

The experiment was established at the experimental farm of the Faculty of Agronomic Engineering and Zootechnics under the Benemerita Universidad Autonoma de Puebla-BUAP, located in Los Reyes de Juarez (Puebla). The quality evaluation of quail meat was performed at Colegio de Postgraduados Campus Montecillo (State of Mexico), endorsed by the Institutional Committee for the Care and Use of Laboratory Animals of the BUAP.

For the study, 200 female quails with an age of 49 days and a final age of 140 days were used. The birds were housed in 60×90 cm metal cages with five replicates of 10 birds each. The feeding system was in linear feeders and automatic drinkers, providing water and feed *ad libitum*. The design was completely randomized which consisted of four treatments (T1, T2, T3 and T4) with different doses of nopal flour added to feed, 0 (control), 400, 800 and 1200 mg kg⁻¹ respectively. These concentrations were supplied in the feed (Table 1) covering the nutritional requirements established for quails, according to Rostagno *et al.* (2017) recommendations.

Once the experiment was over, the birds fasted for 12 h, two birds were randomly selected from each replicate and the live weight (PV, g) was obtained. Subsequently, the quails were humanely sacrificed by cervical dislocation following the Official Mexican Standard NOM-033-SAG/ZOO-2014 regulations (DOF, 2015). Bleeding was made in two minutes by cutting the jugular vein and the carotid artery, then birds were plucked manually.

Table 1. Quail diet composition at the laying stage.

Ingredients	%
Maize (8% CP)	59.00
Soy paste (47% CP)	29.30
Sand	0.52
Non-cooked oil	0.85
DL-Metionine (99%) [§]	0.41
Lisine (78%) [§]	0.35
CaCO ₃ (38%) ^p	7.99
Dicalcium phosphate (18/21%) [□]	1.09
Vitamins and Minerals [†]	0.15
Salt	0.35
kilograms	100.00
Calculated Analysis (%)	
ME (kcal kg ⁻¹) [*]	2800
Crude Protein (CP)	19.00
Calcium	3.34
Available phosphorus	0.34
Lysine	1.18
Methionine + Cystine	0.96
Tryptophan	0.22
Threonine	0.64

[§]Purity percentage; ^p38% of calcium; [□]18% of phosphorus and 21% of calcium. [†]Intake per kg of feed: vitamin A, 7.33 MUI; vitamin D3; vitamin K3; vitamin B1, vitamin B2; vitamin B6; vitamin B12; folic acid; biotin; Calcium D-Pantothenate; nicotinamide; choline chloride; calcium; iron (EDDI, as a source of iodine); zinc; manganese 44 g kg⁻¹; copper; selenium; antioxidant; *ME, metabolizable energy; PC, crude protein.

Carcass yield, Organ length and weight

After the plucking process, the non-chilled carcass was weighed with viscera (CCLC, g) and without viscera (CCLS, g). Non-chilled carcass yield (RCC) was calculated as the percentage difference between the weight of the live bird and the weight of non-chilled carcass plucked and eviscerated. Subsequently, several specific characteristics of the organs were measured using precision equipment, in the proventriculus we measured the width (APRO, mm), length (LPRO, mm) and weight (PPRO, g); also, weight of gizzard without *digesta* (PMO, g), and its width (AMO, mm) and length (LMO, mm). Liver weight (PH, g) was also recorded. Organ length measurements were made with a HER-411 digital caliper (Stern[®], Mexico), while weights were determined with a tactile analytical balance (VELAB, AE224C, USA).

Measuring pH in muscle

To determine the pH in muscle, readings were taken in a cross-section that was made in the muscle *Flexor perforans* of the right leg at 5 min *postmortem*. A table potentiometer

(Model SM- 25CW MICROPROCESSOR pH/ mV METER, USA) was used for the measurement. That instrument was previously calibrated with buffer solutions (pH 4.01, 7.00 and 10.01) to ensure the accuracy of the readings. The electrode was inserted at similar points in the muscle and three measurements were made at each point; after each reading, the electrode was cleaned with distilled water. Finally, the average of the measurements was calculated to obtain the final record value.

Weight of chilled carcass, chilled legs and cooking yield of legs

The samples were stored in refrigeration at 4 °C, and at 24 h *postmortem* the weight of the chilled carcass (CF, g) was obtained, and subsequently the yield of the chilled carcass (RCF, %) was determined. Next, the chilled left leg (PF, g) was cut and weighed with an analytical balance (Model AE224C Electronic Balance); then each one was identified for the cooking process. Ten samples per treatment were introduced into a pot with 500 mL of water, they were placed on an electric grill (Voltec basic, China) for 30 min until reaching 100 °C of internal temperature (Honikel, 1987). After cooking, legs were dried with disposable towels, cooled to room temperature and weighed again. Cooking yield (CR, %) was calculated by difference with the initial weight recorded at 24 h *postmortem*.

Meat color

Subsequently, the color of the meat was evaluated, for this the complete piece of breast (*Pectoralis major*) was extracted and, placed on a white plastic board, a colorimeter was used (Model CR-410, Tokyo, Japan), and the variables luminosity (L*), red-green color tendency (a*) and yellow-blue tendency (b*) were determined.

Meat Texture (MT)

The texture of the meat was measured with a texture-meter (TA-XT2, TextureTechnologies[®] and a Warner-Bratzler[®] knife), breast samples were taken, cut into fillets 1 cm (width), 1 cm (height) and 3 cm (length). First, the texturometer was calibrated and synchronized with the computer program, once calibrated, the samples were placed on the tray so that the blade made the cut with a speed of 5 mm s⁻¹. The data obtained were recorded in a graph generated by the texture-meter software (Lyon & Lyon, 1996).

Water Holding Capacity (WHC)

To evaluate the water retention capacity, the centrifugation method was used; 5 g of meat were taken, finely chopped and placed in a centrifuge tube (in duplicate), 5 mL of 0.6 M NaCl was added to each sample and shaken with a glass rod for 1 min. Tubes were then left to sit in an ice bath for 30 min, then, they were centrifuged for 15 min at 10 000 rpm. The supernatant was decanted and its volume was measured in a test tube. Finally, the amount of solution retained per 100 g of sample was calculated (Guerrero *et al.*, 2002).

Statistical analysis

For this study, a completely randomized design was used, through the GLM procedure SAS[®], to determine if there were significant differences between the means of the

treatments. Once this difference was proved, the Tukey's test was applied, with a 5% alpha error limit ($p \leq 0.05$). The analyses were performed following the routines described in SAS[®] user's manual (SAS Institute Inc., 2017).

RESULTS AND DISCUSSION

Nopal flour concentration did not show a significant effect ($p > 0.05$) on live weight (PV) nor the other carcass variables (CCLC, CCLS, CF, RCC and RCF), which suggests that the additive, in concentrations up to 1200 mg kg^{-1} , does not modify those variables (Table 2). Badr *et al.* (2019) found that the incorporation of up to 15% prickly pear husk in the diet of broilers increased the final weight, suggesting a positive effect on growth. On the contrary, Moula *et al.* (2019), with 5% and 10% addition of prickly pear cladodes in broiler diets, reported no significant effect on weight. Regarding the yield of carcass, Benteboula *et al.* (2023) found that it decreased when they added a meal, based on prickly pear husk between 20% and 40%, to the diet of broilers. This is, there is variability in the response depending on the type and amount of the additive used.

Results showed that the variables PPRP, LPRO, APRO, PM, AMO and PH were not significantly affected by the concentrations of nopal flour (Table 3). However, a significant increase ($p \leq 0.05$) in gizzard length (LMO) was observed when the 400 mg kg^{-1} concentration of nopal flour was used. It seems that the increase in gizzard length alone does not produce an improvement in slaughter weight. Whereas Betenboula *et al.* (2023) found that when using 10% prickly-pear seed meal in poultry, the weight of the liver, proventriculus and gizzard increased compared to the control. By using such a concentration, the fiber content of the diet increased and stimulated the activity of digestive muscles as a result of the reduction in particle size, which improved digestion through a increased retention time and shortened the grinding time (Tejeda and Kim, 2021).

The effects of nopal flour on the physicochemical properties of quail meat are shown in Table 4, the analyses showed that PF, PDC, RC and MT were not significantly affected ($p > 0.05$) by the treatments. The trait MT, which assesses the ease of cutting during chewing, remained constant regardless of treatment, as it is influenced by the number, diameter, and type of muscle fiber, type of connective tissue, collagen, and amount of intermuscular

Table 2. Effect of the inclusion of nopal flour in the feed on the slaughter variables of Japanese quails.

Treatments	PV (g)	CCLC (g)	CCLS (g)	CF (g)	RCC (%)	RCF (%)
T1	224.46	182.00	167.48	171.12	74.47	74.16
T2	218.04	174.48	159.38	159.30	73.15	73.11
T3	217.60	176.36	159.32	159.52	73.23	73.06
T4	216.26	174.42	159.96	159.95	74.23	74.22
SEM	4.13	3.26	3.19	3.19	0.49	0.50
p value	0.9070	0.8380	0.7768	0.5995	0.7189	0.7580

T1, witness; T2, 400 mg kg^{-1} of nopal flour; T3, 800 mg kg^{-1} of nopal flour; T4, 1200 mg kg^{-1} of nopal flour; PV, live weight; CCLC, non-chilled carcass with viscera; CCLS, non-chilled carcass eviscerated; CF, chilled carcass (24 h *postmortem*); RCC, non-chilled carcass yield; RCF, chilled carcass yield; SEM, standard error of the mean.

Table 3. Organ weights in Japanese quails fed with different added concentrations of nopal flour.

Organs	T1	T2	T3	T4	SEM	p value
PPRO (g)	0.80	2.60	1.36	1.90	0.36	0.3717
LPRO (mm)	17.94	18.94	19.21	18.88	0.36	0.3559
APRO (mm)	8.37	8.14	8.35	8.01	0.37	0.6197
PMO (g)	3.14	3.30	3.46	3.36	0.37	0.6088
LMO (mm)	21.66 ^{ab}	22.48 ^a	22.31 ^{ab}	21.07 ^b	0.37	0.0411
AMO (mm)	19.13	18.09	18.45	18.10	0.38	0.3097
PH (g)	4.74	5.14	4.92	4.36	0.38	0.4093

T1: control; T2, 400 mg kg⁻¹ of nopal flour; T3, 800 mg kg⁻¹ of nopal flour; T4, 1200 mg kg⁻¹ of nopal flour; PPRO, proventricule weight; LPRO, proventriculus length; APRO, proventriculus width; PMO, gizzard weight; LMO, gizzard length; AMO, gizzard width; PH, liver weight; SEM, standard error of the mean. Means with different letters between columns are significantly different ($p \leq 0.05$).

fat (Wright *et al.*, 2018). The pH was higher in the control treatment (T1) ($p \leq 0.05$) and decreased with the concentrations of nopal flour. Jankowiak *et al.* (2021) mentioned that a lower pH is correlated with an increase in luminosity (L*) since proteins are denatured and as a consequence the light-scattering properties increase, which coincides with this research; when the pH was lower the meat was brighter due to the effect of nopal flour (Table 4).

The luminosity (L*) of the meat increased ($p \leq 0.05$) in the T3 and T4 treatments, while it decreased with the lowest concentration of nopal flour (400 mg kg⁻¹) and in the control. On the other hand, the intensity of red (a*) was only lower ($p \leq 0.05$) in T2 and was higher in treatments T1, T3 and T4, which could be important since quail is a red meat. Cori *et al.* (2014) found that higher myoglobin content is associated with increased redness in quail meat, chicken meat, and hen meat. Regarding the intensity of the yellow color (b*), it was higher ($p \leq 0.05$) in the control and decreased due to the addition of nopal flour. Treatment

Table 4. Physicochemical characteristics of quail meat supplemented with nopal flour.

Variables	T1	T2	T3	T4	SEM	p value
PF (g)	7.03	7.03	6.80	6.94	0.13	0.9229
PDC (g)	5.55	5.59	5.24	5.39	0.12	0.7425
RC (%)	78.88	79.70	77.32	75.23	1.04	0.4525
MT	14.06	12.15	14.91	12.92	0.49	0.1971
pH	7.27 ^a	6.45 ^c	6.40 ^c	6.72 ^b	0.04	<0.0001
L*	49.64 ^b	50.49 ^b	52.75 ^a	52.61 ^a	0.20	<0.0001
a*	13.26 ^a	12.16 ^b	12.90 ^a	13.11 ^a	0.09	<0.0001
b*	4.09 ^a	2.67 ^b	3.24 ^{ab}	2.91 ^b	0.15	0.0042
WHC (mL per 100g)	25.61 ^b	36.03 ^a	27.45 ^b	27.72 ^b	1.09	0.0024

T1, control; T2, 400 mg kg⁻¹ of nopal flour; T3, 800 mg kg⁻¹ of nopal flour; T4, 1200 mg kg⁻¹ of nopal flour; PF, chilled leg weight (24 h postmortem); PDC, leg weight after cooking; RC, cooking yield; MT, meat texture; pH, hydrogen potential; L*, luminosity; a*, red; b*, yellow; WHC, water holding capacity; SEM, standard error of the mean. Means with different letters between columns are significantly different ($p \leq 0.05$).

T2 was the one that had the greatest reduction in this intensity (34.72%), while T3 and T4 reduced yellow intensity by 20.79% and 28.86%. Treatment T2 was the one with the highest WHC, which could cause a dilution in yellow pigmentation (Roza *et al.*, 2018). This decrease in yellowing may not negatively influence quail meat quality, since it is red; unlike chicken meat, which is white.

The WHC in quail meat was lower ($p \leq 0.05$) in T1, T3 and T4, while meat with the lowest concentration of nopal flour (400 mg kg^{-1}) was the one in which the proteins of the muscle tissue retained the most water quantity. That is, it was the juiciest, which means that at this additive concentration, the antioxidant compounds of the nopal positively influenced the muscle fibers to increase WHC. This finding coincides with Aquino *et al.* (2020) who, by adding antioxidants to the diet of rabbits, also increased WHC. This property is related to the dryness or juiciness of the meat during chewing and the latter is related to meat tenderization (Warner, 2023). The WHC is affected when the pH reaches 5.4, which is the isoelectric point of the myosin protein. This produces retraction of muscle fibrils, thus decreasing juiciness of the meat (Sánchez *et al.*, 2019). In our research pH ranged from 7.27 to 6.40, therefore the decrease in water holding capacity is not attributed to pH.

CONCLUSIONS

The addition of nopal flour in the quail diet did not modify the weight at the time of slaughter. Neither the yield and weight of both non-chilled and chilled carcasses. It also did not affect the proventriculus weight nor its width, as well as those of gizzard and liver.

In regard to meat quality, nopal flour did not influence the weight of chilled legs, cooking yield or meat texture. However, it is an additive that decreases the pH of the meat, increasing luminosity and accentuating the red color, while the yellowing decreases. In addition, with a concentration of 400 mg kg^{-1} of nopal flour, the water retention capacity increased, resulting in juicier meat.

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