Effect of Stocking Density and Supplementation of Potato Peel (Solanum tuberosum L.) Powder and Extract on Productive Performance and Some Carcass Characteristics of Japanese Quail

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Abstract

This study evaluated the effects of stocking density and supplementation of potato peel (*Solanum tuberosum* L.) powder and extract on productive performance and some carcass characteristics of Japanese quail. A total of 810 quail chicks were used in this study. Six dietary treatments and two stocking densities were carried out as an experimental factorial design (6×2). The quails were kept in cages 100×50 cm^2 with (15birds/replicate), and (30 birds/replicate). Chicks were fed experimental treatments from7 to 42 days of age; as a control diet without supplementation (T1). In second and third treatments, potato peel extract was supplemented at (15& 30 ml .l-^{1}) in drinking water;(15 & 30 g.kg-^{1}) potato peel powder (T4, T5) in basal diet, PPE at(15ml.l-^{1}) + PPP at 15g.kg-^{1}) were added to T6 respectively. Results indicated significant ($p \leq 0.05$) improvement in final body weight, weight gain, feed intake, and feed conversion ratio in supplemented groups than in the control. Production index and economic efficiency are significantly better than control. Un elevation in carcass weight, relative weight of liver, heart, gizzard, thigh in all groups (except T3) as compared to control. Meanwhile, there was a significant decrease in abdominal fat (%). Superiority ($P \leq 0.05$) for low density over the high in PI, and gizzard, while higher density lowered abdominal fat. In conclusion, the supplementation of PPE at 15 ml.l-^{1} + PPP at 15g.kg-^{1} achieved the best performance and best economic efficiency.

Keywords: *poultry, production index, crowding, antioxidants, viscera.*

INTRODUCTION

Poultry production is the most quickly growing agricultural industry. It is usually characterized by meat and egg products (Ren et al 2020). Stocking density largely affects the overall performance of poultry birds such as broilers, and several studies have reported adverse effects of high stocking density on bird growth and productivity (Petek et al 2014; Chegini et al 2018). Increased stocking density of birds slowed growth and development and increased oxidative stress (Jobe et al 2019). High stocking density (20 birds/m2) can harmfully affect broiler growth performance and market weight (Cengiz et al 2015). Keser and Bilal (2010) mentioned that the usage of agricultural by-products in animal feeding is an exercise as old as the domestication of animals. Feeding such phytochemicals improved nutrient digestibility in broiler chickens (Saputra et al., 2016; Aditya et al., 2018).The potato (Solanum tuberosum L.) belongs to the family Solanaceae, which includes tomato, eggplant, and peppers (Noonari et al., 2016). Potatoes are an important food source and are consumed widely all over the world (Mahgoub et al., 2015). Potatoes are a source of various biologically active compounds, such as starch, dietary fibres, amino acids, minerals, vitamins, and phenolic compounds. It also contains antioxidant compounds such as carotenoids, phenols, flavonoids, vitamins C and E (Calliope et al., 2018). The phenolic compounds that are produced by potatoes act as a protective response from bacteria, fungi, viruses, and insects (Akyol et al., 2016). Furthermore, the tubers are high in amino acids and offer energy to the body (Al-Bayati & Ali, 2019). The majority of phenolic compounds are found in the potato cortex and skin tissues (Arun et al., 2015), but as previously stated, about half of the phenolic compounds are found in the potato peel and adjacent tissues, with the rest decreasing in concentration from the outside toward the center of potato tubers (Althawab et al., 2019). Carocho et al. (2018) reported that potato peels are a potential source of natural antioxidants that can be used in the food industry, making it a good alternative to synthetic agents (Sielicka and Małecka 2016; Özkan and Özcan 2017). A study by Sampaio et al., (2021), support the use of potato peels as valuable sources of bioactive compounds and as natural additives in functional food formulations. Additionally, potato peels extracts showed antimicrobial activity (Juneja et al., 2018), and anticancer properties (Reddivari et al., 2007). Sweet potatoes came in a variety of forms in chicken feed, including potato root powder, potato peel, potato leaves, and cooked potatoes (Khan, 2017). Karimi et al., (2014) demonstrated that potato powder with or without glucanases enzyme may be utilized as a substitute for maize in the diet of quail without affecting their performance. The antioxidant components in purple sweet potato peel, when combined with fermented cow's milk, can enhance blood lipid status in rats fed a high-fat diet, according to Althawab et al. (2019). Nasoetion et al. (2019) found that adding purple sweet potato extract (25 $ml.kg^{-1}$) to broiler feed resulted in an increase in growth rate, feed intake, feed conversion ratio, and a decrease in cholesterol and low-density lipoproteins in the blood. In addition, the poultry industry has recently witnessed a trend towards exploiting productivity in the best ways, including increasing the number of birds per square meter. The high density per unit area is one of the main sources of profit increase by utilizing the unit area, but this increase may cause problems during the rearing period. Where studies confirmed the possibility of mitigating the impact of high density on birds through the additions of natural antioxidants (Nasoetion et al., 2019). In view of the nutritional and biological properties contained in potatoes and due to the lack of local studies on their use as sources of phytochemical compounds in the diet of poultry and within different densities of birds, this study was designed to investigate the effect of the density of birds and the supplementation of potato peel extract and powder as sources of phytochemicals on productivity and carcass characteristics. As well, to investigating the best density of birds and the best level of natural additives that reduce the effect of high density of birds.

Material & Methods

Animals, diets, and management

The experiment took place from 28 /December/ 2020, to 7/February/ 2021, at the Quail Farm, Department of Animal Production, College of Agriculture, University of Basrah. In a thoroughly randomized design with a 6 x 2 factorial arrangement of treatments, 810 one-day-old quail chicks were weighted and then randomly dispersed into six feeding treatments with two stocking density. The quail chicks were reared under a cage breeding system. The breeding house temperature was kept at about

35°C during the first 3 days, 32°C during the next 4 days, and gradually decreased by 2°C weekly until the final temperature was achieved at 24°C during the 42-day trial Throughout the experiment, all quails had free access to mash feed and freshwater, and the light was provided continuously for 24 h. Birds housed with a stocking density of 333 cm²/birds (15 birds per duplicate) and 167 cm²/birds (30 birds per replicate). Chicks were fed six different experimental diets for eight weeks, as well as a control diet with no supplements (T1). In the second and third treatments, potato peel extract (PPE) was supplemented in drinking water at (15 and 30 ml. l^{-1}) (15 and 30 g.kg^{-1})) potato peel powder (PPP) (T4, T5) in the baseline diet, and potato peel extract (15 ml.l^{-1}) + potato peel powder (15 g.kg^{-1}) in treatment six, respectively. Chicks were fed a basal diet of 24% protein and 2921 kcal.kg^{-1}), till 6 wk of age.Table 1 shows the basic diets established according to NRC (1994). Chemical analysis of potato peel powder was carried out according to AOAC (2016) (Table 2)

Table 1. Ingredients and nutrient composition of quail basal diets

Ingredients	Basal diet (%)
Maize	50.00
Wheat	8.75
Soybean meal (48%)	34.00
[1]protein concentrates (44%)	5.00
Dicalicum phosphate	0.50
Limestone	1.00
Mineral premix	0.30
Sodium chloride	0.30
DL-methionine	0.15
Total	100
Calculated composition[2]	
Metabolizable energy(Kcal /Kg)	2921
Crude protein	24.00
Crude fat	2.97
Crude fiber	2.54
Calcium (%)	0.84
Phosphorus available	0.36
Lysine	1.30
Methionine	0.48
Methionine + Cysteine	0.82

1Protein concentrate used from Al-Hayat Company , Jordanian Origin, to provide the following per kg of diet: 44% protein, 2800 kcal/kg ME, 12% fat, 25% ash, 5% calcium, 2.9% phosphorus, 2.55% methionine + Cysteine, 2.8% lysine. 2Was calculated according to of feedstuff contained in NRC (1994).

Preparation of potato peel powder (PPP):

Potato peels (Solanum tuberosum L.) used in this study were obtained from potatoes factory processing for the food industry (crisps, chips, mashed potatoes) in Basra City.The collected potato peels were washed, sundried, crushed into meal and stored for later use.

Table 2. Chemical analysis of potato peels powder:

Compounds	**Percentage%**
Dry matter	88.60
Moisture	11.40
Crud protein	12.23
Crud fiber	2.31
Total Ash	1.82
Crud fat	0.22
Nitrogen free extract	83.42
Organic mater	98.18
*Metabolic energy kcal/kg	3431.74

Metabolizable energy calculated according to (Pauzenga , 1985) as:

ME (Kcal/Kg) = 37× %CP + 81× %EE + 35.50 × %NFE.

Preparations of potato peel extract (PPE):

To make the methanol extract of potato peel powder, 10 (g) of ground materials are mixed with (100 ml) of methanol alcohol in a shaker at room temperature overnight, then filtered through Whatman No.1 filter paper. Under the same circumstances, the leftovers were re-extracted. In a rotary evaporator, the mixed filtrates were evaporated at temperatures below 40 0C. After evaporation of the methanol, the potato peel extracts were kept at (-20) 0C for further use (Mohdaly, et al., 2010).

Bird's performance:

The live body weight (LBW) was measured at the start of the study and then every week after that. We estimated weight gain (WG), feed intake (FI), feed conversion ratio (FCR), and economic efficiency (EE). The following equation was used to determine the Production Index (PI) (Martins, et al. 2016):

$$\text{Production Index(PI)} = \frac{\text{Average of live weight in (gm)} \times \text{liveability percentage} \times 100}{\text{Age in days } \times \text{FCR}}$$

Liveability percentage = 100 – mortality percentage

Carcass traits

Six birds (three males and three females) were randomly selected from each treatment at 42 days of age and utilized to analyze carcass features. The carcass weight of selected birds was estimated after they were weighed individually and murdered. Internal organs (liver, heart, and gizzard) as well as abdominal fat were taken, weighed, and expressed as a percentage of live body weights. The carcass cuts (breast and thigh yield) were calculated as a percentage of the total weight of the carcass. According to the equation, the proportion of dressing was computed (Brake et al., 1993).

$$\text{Dressing percentage (DP)} = \frac{\text{Dressed weight (gm)}}{\text{live weight (gm)}} \times 100$$

Statistical analysis

Using the SPSS software (2015) statistical application of the 2-way ANOVA approach, a factorial analysis was undertaken to examine the main effects (Treat and density) and their interaction. Duncan's multiple range tests (Duncan's, 1955) were also used to assess significant differences between means at a 5.0 % level of significance.

Results & Discussion

The impact of stocking density and nutritional supplementation with potato peel powder (PPP) and extract (PPE) on quail chick productivity is shown in Table 3. The results showed that all additional treatments enhanced final body weight, total weight increase, feed intake, and feed conversion ratio considerably ($P \leqslant 0.05$) when compared to the control. The results demonstrate that quail chicks given the (PPE at 15 $ml.l^{-1}$ + PPP at 15 $g.kg^{-1}$) (T6) diet had the highest body weight, weight gain, and feed conversion ratio value when compared to the other treatments. The results revealed that the additions of PPP, PPE, and cage density had no significant interaction . The antioxidant activity of the components of the PPP and PPE led in enhanced intestinal health and increased nutritional digestion and absorption, which may explain why adding potato peel powder or extract improved quail performance. In this regard, Althawab et al., (2019) shown that sweet potato peel extract has a high likelihood of being used as an antioxidant in food systems due to its high phenolic content. Purple sweet potato extract supplementation (at 0, 25, and 50 ml/kg)diet significantly increased protein intake, protein digestibility, and meat protein mass in broilers, according to Saputra et al., (2016). When Kanatt et al., (2005) evaluated the antioxidant activity of potato peel extract with commercial antioxidants, he discovered that it was similar to butylated hydroxyl toluene (BHT). In contrast, Mohdaly et al., (2013) found that, in addition to artificial antioxidants, potato peels had a higher anti-oxidative impact than sesame cake and sugar beet pulp. According to Amado et al., (2014) findings, the ethanolic extract of potato peel waste was able to stable soybean oil beneath amplified oxidation circumstances, decreasing peroxide, anisidine, and tox values at excessive temperature. Our findings matched those of Nasoetion et al., (2019) found that adding (25 ml. kg $^{-1}$) purple sweet potato extract to broiler chicken feed enhanced growth rate, feed intake, and feed efficiency. In contrast to our findings, Raphael et al., (2017) report that adding sun-dried Irish potato peel meal to the broiler diet had no effect on feed consumption. The findings with respect to stocking density are in accordance with Astaneh et al.,(2018) who reported that feed conversion ratio, body weight gain, and feed intake were improved significantly in 12 chicks density compared to 18 chicks of Ross 308 broilers. Bahşi, et al.(2016) reported that high stocking densities reduced body weight gain, except to add a dose of 400 ppm oleuropein, which caused an increase in body weight gains, and improved feed conversion rate in both stockings densities (12, 18 birds/cage) groups. In another study, Mahrose et al. (2019) reported that the low stocking density was adequate in the superior performance of quails than that of the high stocking group. Stocking densities and the use of potato peel powder or extract had a significant effect on the production index (PI) (Table 2). Supplementing with PPP and PPE increased PI levels considerably ($P \leqslant 0.05$). On day 42 of the study, the greatest value of PI was reported in treatment T6 (14.91), while the lowest value was recorded in the control diets (9.38). The production index significantly was better ($P \leqslant 0.05$) at low densities than the high densities. There were significant interactions between stocking density and supplemented treatments on the value of PI. Gholami, et al (2020) reported that low density (10 chicks/m2) showed the highest production index. In terms of economic efficiency (EE) value, the results showed that EE values in supplemented treatments were significantly lower ($p \leqslant 0.05$) than in control, indicating that supplemented treatments had the best economic efficiency value. The lack of mortality and a superior feed conversion ratio in supplement treatments favorably reflected the improvement in PI and EE values.

Table 3. Effect of stocking density and experimental treatments on productive performance of quails at overall period 7-42 days

Items	Density	Experimental diets						Mean	SEM	*P-Values**
		T1 (0.0)	T2 (15 m/l PPE)	T3 (30 m/l PPE	T4 (15g/kg PPP)	T5 (30 g/kg PPP)	T6 (15PPP + 15PPE)			
IBW (g)	D1	33.66	33.69	33.67	32.98	33.63	33.98	33.60	0.240	T= 0.913
	D2	33.64	34.01	33.33	33.66	33.35	33.66	33.61	0.133	D= 0.987
	Mean	33.65	33.85	33.50	33.32	33.49	33.82	33.60	0.135	T×D= 0.907
FBW (g)	D1	162.80	179.10	185.34	179.23	179.11	187.83	178.90	2.083	T = 0.000

	D2	164.25	180.94	177.86	177.35	177.93	185.30	177.27	1.618	D=0 .135
	Mean	163.53c	180.02a	181.60a	178.29b	178.52b	186.57a	178.09	1.306	T × D =0.172
WG	D1	129.14	145.40	151.67	146.24	145.48	153.85	145.30	2.04	T=0.000
	D2	130.61	146.93	144.53	143.69	144.57	151.64	143.66	1.60	D=0.106
	Mean	129.88c	146.17a	148.10a	144.96b	145.02b	152.74a	144.48	1.28	T×D= 0.149
FI(g)	D1	603.10	554.43	540.25	562.18	551.85	528.97	556.79	6.825	T = 0 .002
	D2	602.54	537.60	552.30	552.44	512.55	535.57	548.83	9.476	D= 0.396
	Mean	602.82 a	546.01b	546.27b	557.31b	532.20b	532.27b	552.81	5.790	T × D = 0.396
FCR	D1	3.70	3.97	2.91	3.13	3.07	2.82	3.12	0.053	T = 0.000
	D2	3.66	3.93	3.10	3.11	2.88	2.88	3.10	0.074	D=0. 692
	Mean	3.68a	3.02bc	3.00bc	3.12 b	2.97bc	2.85c	3.11	0.115	T × D = 0. 343
PI	D1	9.75	13.80	15.20	13.62	13.88	15.20	13.57A	0.466	T = 0.0001
	D2	9.01	14.55	11.82	13.04	14.75	14.62	12.96B	0.536	D=0.0458
	Mean	9.38 c	14.18ab	13.51b	13.33b	14.32a	14.91a	13.26	0.381	T × D =0.0040
EE	D1	2594.67	2163.00	2037.00	2193.33	2151.33	1969.33	2184.78	51.485	T=0.0001
	D2	2564.33	2076.67	2172.33	2177.00	2009.00	2020.67	2170.00	52.190	D= 0.692
	Mean	2579.50a	2119.83bc	2104.67bc	2185.17b	2080.17bc	1995.00c	2846.52	35.779	T × D = 0. .343

abc Means in the same row with no common superscript are different at p ⩽ 0.05, AB Means in the same column with no common superscript are different at p ⩽ 0.05. SEM : Standard error of the mean, PPE: Potato peel extract; PPP: Potato peel powder, P-value*, T= Treat effect, D: Density effect, T×D = Interaction effect, D1: 15 chicks/replicate; D2: 30chicks/replicate; IBW: Initial live weight; FBW: Final body weight; FI: Feed intake; FCR: Feed conversion ratio (FI/FBW), PI: Production index, EE: Economical efficiency.

Table 4. Effect of stocking density and experimental treatments on carcass traits of quails at 42 days of age

Characteristic	Density	Experimental diets						Mean	SEM	*P-Values**
		T1 (0.0)	T2 (15 m/l PPE)	T3 (30 m/l PPE	T4 (15g/kg PPP)	T5 (30 g/kg PPP)	T6 (15PPP + 15PPE)			
Dressing percentage*	D1	61.09	62.99	64.85	64.23	65.90	65.48	64.09	0.803	T = 0.604
	D2	57.85	63.57	63.26	61.42	44.81	62.56	58.91	3.11	D=0.128
	Mean	59.47	63.28	64.05	62.82	55.35	64.02	61.50	1.443	T × D =0.457

Carcass weight (g)	**D1**	**91.83**	**107.50**	**118.00**	**110.00**	**117.83**	**106.33**	**108.58**	**2.98**	**T = 0.014**
	D2	**92.80**	**108.53**	**106.66**	**106.83**	**115.83**	**110.83**	**106.91**	**2.72**	**D=0.642**
	Mean	**92.31^{b}**	**108.01^{a}**	**112.33^{a}**	**108.41^{a}**	**116.83^{a}**	**108.58^{a}**	**107.75**	**1.99**	**T × D =0.848**
Breast yield (%)	**D1**	**33.82**	**39.53**	**32.72**	**34.34**	**32.64**	**33.19**	**34.37**	**0.860**	**T = 0.258**
	D2	**32.62**	**34.33**	**34.18**	**32.89**	**33.77**	**34.06**	**33.64**	**0.564**	**D=0.469**
	Mean	**33.22**	**36.93**	**33.45**	**33.61**	**33.21**	**33.62**	**34.01**	**0.510**	**T × D =0.404**
Thigh yield (%)	**D1**	**14.17**	**16.60**	**15.86**	**17.70**	**16.08**	**15.68**	**16.01**	**0.350**	**T =0.000**
	D2	**13.95**	**15.99**	**14.21**	**17.22**	**17.88**	**15.43**	**15.78**	**0.417**	**D=0.556**
	Mean	**14.06^{d}**	**16.29^{abc}**	**15.04^{cd}**	**17.46^{a}**	**16.98^{ab}**	**15.56^{c}**	**15.90**	**0.269**	**T × D=0.273**
Liver weight (%)	**D1**	**2.10**	**2.64**	**3.54**	**3.27**	**2.78**	**3.33**	**2.94**	**0.156**	**T =0 .005**
	D2	**2.03**	**2.90**	**2.43**	**3.26**	**2.89**	**2.56**	**2.68**	**0.127**	**D=0.106**
	Mean	**2.06^{b}**	**2.77^{a}**	**2.98^{a}**	**3.27^{a}**	**2.84^{a}**	**2.94^{a}**	**2.81**	**0.101**	**T × D =0.110**
Heart weight (%)	**D1**	**.660**	**.890**	**.860**	**.920**	**.840**	**.960**	**.850**	**0.026**	**T = 0.000**
	D2	**.630**	**.850**	**.860**	**.900**	**.830**	**.910**	**.830**	**0.023**	**D=0.198**
	Mean	**$.65^{d}0$**	**$.87^{bc}0$**	**$.86^{bc}0$**	**$.91^{b}0$**	**$.83^{c}0$**	**$.94^{a}0$**	**.840**	**0.017**	**T × D =0.964**
Gizzard weight (%)	**D1**	**1.98**	**2.70**	**2.28**	**2.29**	**2.25**	**2.84**	**2.39A**	**0.092**	**T =0 .112**
	D2	**1.82**	**2.12**	**2.32**	**2.17**	**2.49**	**2.03**	**2.16B**	**0.090**	**D=0.052**
	Mean	**1.90^{b}**	**2.41^{a}**	**2.30^{a}**	**2.23^{a}**	**2.37^{a}**	**2.44^{a}**	**2.27**	**0.066**	**T × D =0.114**
Abdominal fat (%)	**D1**	**1.04**	**.740**	**.870**	**.660**	**.740**	**.870**	**$.82^{A}0$**	**0.032**	**T = 0.000**
	D2	**1.02**	**.650**	**.810**	**.640**	**.720**	**.860**	**$.78^{B}0$**	**0.031**	**D=0.015**
	Mean	**1.03^{a}**	**$.69^{c}0$**	**$.84^{b}0$**	**$.65^{d}0$**	**$.73^{c}0$**	**$.86^{b}0$**	**.800**	**0.022**	**T × D = 0.481**

abcMeans in the same row with no common superscript are different at p ≤0.05,AB Means in the same column with no common superscript are different at p≤0.05. SEM: Standard error of the mean, PPE: Potato peel extract; PPP: Potato peel powder, P-value*, T= Treat effect, D: Density effect, T×D = Interaction effect, D1: 15 checks/replicate; D2: 30checks/replicate.

Table 4 shows the effect of stocking density and experimental treatments on quail carcass characteristics at 42 days of age. All treatments and two stocking densities had similar dressing percentages and breast yield (%). However, dietary supplementation with potato peel powder and extract led to a substantial (P≤ 0.05) increase in carcass weights and relative weights of liver, heart, gizzard, and thigh, whereas all supplementation treatments exhibited less (P≤0.05) abdominal fat relative weight than control Table 4. The results also revealed a significant (P≤0.05) difference in relative gizzard weight between low and high stocking density, as well as reduced abdominal fat in high stocking density quail. This study's improvement in carcass weight with the addition of potato peel and extracts might be attributed to a greater conversion of nutrients in the potato peel supplemented diet into the meat. Ahaotu et al., (2011) found that consuming 25% sweet potato resulted in significantly improved body weight, thigh length, leg length, and heart weight. Raphael et al., (2017) reported significant improvements in gizzard and liver relative weight in broilers fed graded amounts of sun-dried Irish potato peel meal. In contradictory an earlier study Karimi et al.,

(2014) reported that supplementing with dry potato powder and glucanases enzyme, leads to decrease breast meat weight, with no change in wings, drumstick, intestinal, and gizzard weights between treatments of Japanese quail.

Regarding Stocking density Kryeziu et al., (2018), reported that broilers reared with the lower and medium stocking density (14 and 18 birds/m2) had higher carcass weights compared to high stocking density (22 birds/m2),

with no change in dressing percentage. As well, improved carcass weight and meat yield were noted when Arbor Acres broilers were reared at 15 bird/m2 (Abo Alqassem et al., 2018), whereas, high density (more than 15 bird/m²) significantly reduce the carcass quality, especially thigh, breast yield, and lower breast fillet (Abo Ghanima et al. 2020). In contrast to the current study, Uzum & Toplu (2013) found that stocking density had no effect on carcass weight. In terms of the influence of stocking density on abdominal fat, our findings, which accord with Sang et al., (2021) revealed that when Korean Native broiler chicks gave Scopoletin under two stocking densities, abdominal fat was reduced in the high stocking density treatments. Our results are contradictory with (Astaneh et al., 2018) who stated that stocking density had no significant effect on abdominal fat.

Conclusion

On the basis of the findings, it can be concluded that supplementary potato peel extract (PPE) at a concentration of (15 and 30 ml.l-^{1}) in drinking water; (15 and 30 g.kg-^{1}) potato peel powder (PPP); and their combination (15 PPE+ 15 PPP) have a positive impact on productive performance and some carcass traits. In addition, high quail density reduced abdominal fat, but low density increased the production index.

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AUTHOR'S CONTRIBUTION

Rabia J. Abbas, supervised the study; Zainab A. Mutter implemented the study and wrote the manuscript.

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