Influence of the Dietary Supplement of Protected Calcium Butyrate in Growing Japanese Quail Diets on Performance, Carcass Parameters, Blood Serum Biochemical Status, Meat Quality, and Jejunum Histomorphology

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ABSTRACT

The effect of protected calcium butyrate (PCB) supplemented at different amounts on performance, carcass characteristics, blood biochemical values, jejunum histomorphology, and meat traits in Japanese quails were determined. One-day-old unsexed Japanese quails were divided into four groups with seven replicates of seven birds. A conventional corn and soybean meal-based diet was formulated, and all groups' diets were supplemented with 0, 0.5, 1.0 and 2.0 g/kg PCB respectively for 42 days. From the results, PCB supplementation significantly improved body weight (BW) on the 21st day, body weight gain (BWG) between 0 to 21 days, hot carcass yield (HCY), and relative weights of the hearth. Similarly, blood urea nitrogen (BUN), total cholesterol (TC), low-density lipoprotein (LDL) and villus height (VH) levels were lower in PCB-supplemented groups. Besides, PCB supplementation in Japanese quails decreased the villus-crypt rate (VCR) except for the control and the group fed with 2.0 g/kg PCB. This study showed that dietary PCB supplementation in Japanese quails' diet improved growth performance in young chicks and carcass yield, BUN, and lipid profile. On the other hand, the supplementation did not affect the antioxidant status, homocysteine, and folic acid values in blood and meat traits.

Introduction

Butyric acid, which is produced by the colonic microbiome, is an important short-chained fatty acid (SCFA) in poultry nutrition due to its ability to improve intestinal absorption both stimulating epithelium proliferation and impairing health in the intestines of the poultry (1, 9, 17). Because free salt forms of organic acids are commonly dissolved and absorbed in upper digestive tract organs; salt forms of butyric acid, such as sodium and calcium butyrate, are commonly used instead of acid forms; (17, 19). Due to the low pH of upper digestive organs; butyrate salts it's quickly converted to the undissociated form, butyrate needs to be protected with fat or film coating or micro-encapsulation to improve efficiency in the intestines (9, 12).

Butyric acid is not only important in animal nutrition because of its boosting effect on performance, but it also has a protective effect on metabolism by anti-carcinogenic, anti-inflammatory, and antioxidant properties (9, 30). Although the antioxidant effect of

dietary butyrate implementation in poultry was stated by several researchers (8, 12, 29), it is not clearly understood the effect mechanism of butyric acid reactive oxidant species.

Folate or folic acid (FA) is a water-soluble vitamin that involves one on -carbon metabolism and is required for the homocysteine remethylation process to form methionine and in the biosynthesis of amino acids deoxynucleotides essential for DNA replication and repair (5, 25). The absorption of FA could be established both from the diet and from the bacterial synthesis in the colon. Although FA is absorbed both in the intestines and the colon, it appears to folate mostly taken in from the jejunum (20). The FA deficiency in metabolism is indicated to cause homocysteine accumulation in blood by decreasing cystathionine synthesis and inhibiting homocysteine remethylation. Thus, higher homocysteine levels in the blood also might induce to increase in malondialdehyde levels in tissues (25). In order to promote FA absorption, we hypothesized that dietary protected calcium butyrate may regulate the gut microbiota and jejunum histomorphology in a positive way. This, in turn, may have a positive impact on the blood homocysteine level and the oxidative status of Japanese quails.

Thus, this trial was conducted to investigate the effect of increasing doses of dietary protected calcium butyrate salt supplement on performance, carcass parameters, jejunum histomorphology, blood serum values, and meat quality in Japanese quails.

Materials and Methods

Animals and Management: The six-week feeding experiment included 196 one-day-old unsexed Japanese quail chicks (*Coturnix coturnix Japonica*) which were allocated randomly into four groups of 49 chicks in 7 replicates (7 birds in each replicate). The first group was determined as a control group and fed a basal diet (Table 1). The basal diet was formulated according to National Research Council to meet Japanese quails' nutritional needs (22). Protected calcium butyrate was added at levels of 0.5, 1.0, and 2.0 g/kg in the basal diet respectively for the other groups. The PCB used in the trial subsumed 70% butyrate and coated with palm oil by the microencapsulation method. The PCB levels were determined according to the study conducted by Elnesr et al. (9). All birds accessed feed and water ad libitum.

The quails were reared in the same type of plastic wire floor pens (30 x 80 x 18 cm) under the same conditions and management with 23 hours of artificial lighting per day. The room temperature was set at 35ºC for the first week and decreased to 2-3ºC every week until it was reduced to 24-25ºC.

Performance Trial and Sample Collection: Live weights of the Japanese quails were evaluated on days 0, 21, and 42 of the trial individually with a 0.01 g scale. Supplied feed was recorded daily and feed intake was quantified by subtracting the remaining feed in feeders from the feed given during the period and dividing the total animals into replicates. Feed conversation ratio (FCR) and body weight gain (BWG) were calculated throughout the experimental period.

Table 1. Ingredients and chemical and calculated content of basal diet of growing Japanese quail.

Ingredients (%)	
Barley	10.00
Vegetable Oil	0.50
Maize	49.27
Corn gluten meal	1.72
Soybean meal	35.28
Dicalcium phosphate	0.73
DL-Methionine	0.15
Coccidiostat	0.08
L-Lysine hydrochloride	0.15
Marble powder	1.37
Sodium bicarbonate	0.10
Salt	0.40
Vitamin and Mineral Premix[1]	0.25
TOTAL	**100.00**
Chemical composition (%)	
Dry Matters	88.74
Crude Protein	21.60
Crude Fat	2.01
Crude Ash	7.11
Crude Fiber	5.93
Calculated composition	
Sodium, (%)	0.23
Calcium, (%)	0.85
Phosphorus, (%)	0.31
Lysine, (%)	1.34
Total Met + Sis, (%)	0.93
ME (kcal/kg) [2]	2.533

[1] 1 Kg Vitamin-Mineral Premix contains; 8,800 IU vitamin A, 2,200 IU vitamin D_3, 11 mg vitamin E, 44 mg nicotinic acid, 8.8 mg Calcium D-Pantothenate, 4.4 mg riboflavin, 2.5 mg thiamin, 6.6 mg vitamin B_{12}, 1 mg folic acid, 0.11 mg D-biotin, 220 mg choline, 80 mg manganese, 60 mg iron, 5 mg copper, 60 mg zinc, 0.20 mg cobalt, 1 mg iodine, 0.15 mg selenium.

[2] Metabolizable energy content of diets calculation was conducted according to the equation of Carpenter and Clegg (7).

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All quails fasted for 6 hours before the slaughter. 2 birds from each replicate were randomly weighed and killed by the cervical dislocation method. Blood samples were collected from the jugular vein of the animals. Hot undressed carcass and some organs including heart, liver, proventriculus (PV), gizzard, bursa of Fabricius (BF), and spleen were weighed and calculated relative weights by dividing them into live weights and multiplying by 100. Approximately 20 g of breast meat samples were collected from the hot carcasses after determining the carcass traits. Blood serum was collected after centrifugation for 15 minutes and 3.000 rpm. All samples were stored at -20°C until the day of analyses. Additionally, 1 cm of jejunum section was collected from the intestines for intestinal histomorphology evaluation.

Intestinal Histomorphology: The jejunum samples cleaned with the physiological saline solution were steeped in formol solution for 24 h. Thereafter, tissue samples were dehydrated in 70% ethanol overnight and processed using an automatic tissue processor (Thermo-Fisher, MA, USA). The samples were embedded in paraffin wax and the blocks were kept at +4ºC overnight again. The paraffin blocks were cut at 6 µm thickness on a microtome and stained with Masson's trichrome. Microscopy was implemented using a light microscope (Leica DM 500, Leica Biosystems Nussloch GmbH, Germany). Villus height and crypt depth of each quail were evaluated by taking the average of five measurements with ImageJ software.

Blood Chemistry: Blood urea nitrogen (BUN), glycogen, total protein (TP), albumin, globulin, Ca, P, triglycerides, total lipids, and their fractions were measured with commercial kits (Rel Assay Diagnostics, Gaziantep, Türkiye). Total antioxidant capacity and total oxidant status were analyzed by the diagnostic kits of the same company, spectrophotometrically. Homocysteine and folic acid levels in serum were measured with commercial kits (Wuhan USCN Business Co. Ltd, Wuhan, China) using an ELISA reader (ChroMate® 4300, Awareness Technology, Inc., Palm City, FL, USA).

Meat Quality: Each breast meat sample was divided into 4 parts. The breast meat CIE L* (lightness), a* (redness), and b* (yellowness) values were determined by a Minolta colorimeter (CR-200, Minolta Co., Osaka, Japan). The tissue malondialdehyde (MDA) level was analyzed by a method based on the reaction with thiobarbituric acid (TBA) at 90–100ºC. In this process, 0.1 g of sample was homogenized with phosphate-buffered saline using a probe-ultrasonicator for 10 min (Hielscher-UP100H, Germany). The samples were mixed with two volumes of cold 10% (w/v) trichloroacetic acid for the precipitation of protein. The precipitates were pelleted by centrifugation and the aliquot of the supernatants were reacted with an equal volume of 0.67% (w/v) TBA in a boiling water bath for 10 min. The absorbance was read at 532 nm after cooling. Water holding capacity (WHC) was estimated as; 1.00 g of the breast meat sample was dried in a drying oven for 12 hours after being centrifuged for 4 min at 1.500 rpm. WHC was determined by the following formula: (weight after centrifugation – weight after drying) / initial weight × 100. The rest of the samples were grinned into mince and stored at +4ºC for a month. pH values of mince were measured on 1st, 15th, and 30th days with a portable pH/temperature meter (Milwaukee MW102, USA).

Statistical Analysis: After all data was collected, the statistical analyses were performed using IBM Statistical Package for Social Sciences (SPSS) software for Windows version 26. One-way analysis of variance (ANOVA) is used to determine performance, carcass traits, jejunum micromorphology, blood chemical values, and meat quality of the control and treatment groups. Significance in the trial was based on $P<0.05$. Analysis and means were compared using the Duncan test.

Results

Table 2 shows the effect of PCB on body weight (BW), body weight gain (BWG), feed intake (FI) and feed conversation rate (FCR). In this study highest and lowest BW on the 21st day and BWG between the 1st to 21st days were 2.0 g/kg PCB supplemented group and control respectively ($P<0.05$). Nonetheless, FI and FCR, BW on the 42nd day, and BWG on 22-42 and 1-42 days values showed no difference between groups ($P>0.05$).

In this study, it was seen that dietary PCB supplementation increased average HCY and the best values were in the 0.5 g/kg PCB group among control and other experimental groups ($P<0.05$). Moreover, the quails fed with 2.0 g/kg PCB supplemented diet had the highest relative heart weight of other groups ($P<0.05$). On the other hand, liver, gizzard, PV, BF, and spleen were not changed by PCB ($P>0.05$) (Table 3).

The effect of dietary PCB supplementation on blood serum biochemical values in Japanese quails demonstrates in Table 4. BUN, TC, and LDL concentrations in blood serum changed with PCB ($P<0.05$). BUN concentration was decreased linearly with increasing levels of PCB supplementation in the current research. Besides, the PCB supplementation also decreased TC and LDL values in blood serum. There was no difference between control and dietary treatments in blood serum glycerol, TP, albumin, globulin, Ca, P, TG, HDL, homocysteine, FA, TOS, TAC, and OSI values ($P>0.05$).

The influence of feeding different diets of PCB on jejunum histomorphology is shown in Table 5. No effect was observed in CD contents of jejunum among the control and treatment groups (P>0.05). On the other hand, PCB supplementation depressed VH values compared to control. Furthermore, the control and the group fed with 2.0 g/kg PCB had a greater V:C Rate than the groups that received 0.5 and 1.0 g/kg PCB respectively (P<0.05).

The effects of PCB supplementation to Japanese quail diets on meat quality parameters are shown in Table 6. Our results showed that dietary PCB has no effect on pH values on 1st, 15th, and 30th days, MDA, WHC, and L.A.B. parameters in breast meats (P>0.05).

Table 2. Body weight (BW), body weight gain (BWG), feed intake (FI), and feed conversion rate (FCR) of Japanese Quails supplemented with dietary PCB.

Parameters[1]	PCB Levels (g/kg diet)				*Significance (P-value)*[2]	
	0	0.5	1.0	2.0	L	Q
BW, Day 0, g	8.23±0.11	8.37±0.26	8.41±0.16	8.32±0.29	0.432	0.158
BW, Day 21, g	70.81±9.62^{b}	81.01±6.59^{a}	81.27±7.48^{a}	82.01±3.87^{a}	0.010	0.095
BW, Day 42, g	161.39±10.53	177.14±14.14	172.68±11.07	172.97±11.71	0.147	0.100
BWG, 0-21, g	62.58±9.61^{b}	72.63±6.51^{a}	72.85±7.38^{a}	73.69±3.80^{a}	0.010	0.101
BWG, 22-42, g	90.59±7.18	96.13±11.37	91.41±10.33	90.96±9.93	0.830	0.427
BWG, 0-42, g	153.16±10.53	168.76±14.16	164.27±11.08	164.65±11.70	0.115	0.105
FI, 0-21, g	236.82±18.45	254.22±43.15	241.65±20.15	259.65±25.12	0.256	0.978
FI, 22-42, g	364.63±38.08	387.74±43.76	395.76±60.86	396.71±40.93	0.199	0.537
FI, 0-42, g	601.44±43.37	641.96±68.67	637.41±74.91	656.36±45.26	0.125	0.637
FCR, 0-21, g/g	3.83±0.39	3.53±0.69	3.34±0.34	3.52±0.31	0.162	0.172
FCR, 22-42, g/g	4.02±0.21	4.06±0.52	4.33±0.40	4.37±0.24	0.194	0.992
FCR, 0-42, g/g	3.93±0.15	3.81±0.40	3.87±0.22	3.99±0.16	0.576	0.239
Mortality rate, %	7.14±3.72	10.71±3.26	8.93±5.92	8.93±3.57	0.853	0.678

[a – b] Means with different superscripts within the same line diverge significantly (P<0.05), according to Duncan's test.
[1] BW, body weight; BWG, body weight gain; FI, feed intake; FCR; feed conversation rate.
[2] Data were analyzed using linear and quadratic regression models of SPSS.

Table 3. Hot Carcass Yield (HCY), and relative organ yields of Japanese Quails supplemented with dietary PCB.

Parameters[1]	PCB Levels (g/kg diet)				*Significance (P-value)*[2]	
	0	0.5	1.0	2.0	L	Q
HCY (%)	57.12±4.01^{b}	61.54±2.67^{a}	60.41±4.92^{a}	59.19±2.81^{ab}	0.290	0.010
Liver (%)	2.72±0.70	2.54±0.62	2.70±0.71	2.50±0.66	0.554	0.897
Heart (%)	0.82±0.10^{b}	0.87±0.09^{ab}	0.92±0.15^{a}	0.95±0.10^{a}	0.003	0.632
Gizzard (%)	1.90±0.35	1.78±0.29	1.83±0.41	1.78±0.24	0.425	0.652
PV (%)	0.51±0.10	0.52±0.15	0.52±0.09	0.54±0.06	0.519	0.990
BF (%)	0.08±0.03	0.09±0.03	0.09±0.03	0.08±0.02	0.736	0.353
Spleen (%)	0.05±0.02	0.04±0.01	0.05±0.02	0.05±0.03	0.577	0.705

[a – b] Means with different superscripts within the same line diverge significantly (P<0.05), according to Duncan's test.
[1] HCY, hot carcass yield; PV, proventriculus; BF, bursa of Fabricius.
[2] Data were analyzed using linear and quadratic regression models of SPSS.

Table 4. Biochemical values in blood serum of Japanese Quails supplemented with dietary PCB.

Parameters[1]	PCB Levels (g/kg diet)				*Significance (P-value)*[2]	
	0	0.5	1.0	2.0	L	Q
BUN (mg/dL)	5.76±0.54[a]	5.80±0.54[a]	5.53±0.48[ab]	5.18±0.59[b]	0.007	0.223
Glyc (mg/dL)	345.17±26.57	345.42±24.03	323.42±36.69	337.33±37.58	0.274	0.460
TP (g/dL)	3.03±0.92	2.52±0.60	2.64±0.93	2.45± 0.50	0.105	0.475
Alb (g/dL)	1.75±0.28	1.64±0.31	1.59±0.34	1.58±0.24	0.162	0.580
Glob (g/dL)	1.29±0.66	0.88±0.34	1.05±0.63	0.87±0.32	0.105	0.452
Ca (mg/dL)	33.25±23.50	17.08±10.99	23.25±17.21	17.67±12.98	0.089	0.316
P (mg/dL)	9.23±4.22	7.87±1.58	7.57±3.30	6.88±1.73	0.058	0.697
TC (mg/dL)	263.00±76.94[a]	176.17±38.79[b]	231.00±67.12[a]	222.50±55.99[ab]	0.405	0.032
TG (mg/dL)	396.33±181.56	329.08±183.66	337.17±175.66	273.33±189.44	0.133	0.974
LDL (mg/dL)	77.08±43.70[a]	30.25±17.39[c]	58.75±39.09[ab]	47.09±20.72[bc]	0.158	0.071
HDL (mg/dL)	74.00±33.88	92.42±31.32	79.50±28.26	93.75±30.56	0.254	0.817
HCST (ng/mL)	4.19±1.36	4.65±1.50	4.44±1.30	3.70±1.47	0.383	0.160
FA (pg/mL)	3.09±1.99	2.15±1.30	3.25±0.86	3.15±1.20	0.130	0.081
TOS (mmol/L)	10.14±4.94	8.28±2.32	9.97±2.57	10.85±2.90	0.380	0.163
TAC (mmol/L)	1.54±0.32	1.64±0.39	1.67±0.31	1.63±0.52	0.556	0.552
OSI	0.71±0.43	0.52±0.15	0.60±0.11	0.76±0.40	0.571	0.052

[a – b] Means with different superscripts within the same line diverge significantly (P<0.05), according to Duncan's test.
[1]BUN, blood urea nitrogen; Gcly, glycogen; TP, total protein; Alb, albumin; Glob, globulin; Ca, calcium; P, phosphorus; TC, total cholesterol; TG, triglycerides; LDL, low-density lipoprotein; HDL, high-density lipoprotein; HCST, homocysteine; FA, folic acid; TOS, total oxidative status; TAC, total antioxidant capacity and OSI, oxidative stress index.
[2] Data were analyzed using linear and quadratic regression models of SPSS.

Table 5. Jejunum histomorphology in Japanese Quails supplemented with dietary PCB.

Parameters[1]	PCB Levels (g/kg diet)				*Significance (P-value)*[2]	
	0	0.5	1.0	2.0	L	Q
VH (µm)	644.86±93.83[a]	548.36±94.75[b]	563.90±63.23[b]	614.50±127.51[ab]	0.520	0.007
CD (µm)	95.19±12.00	100.47±13.26	98.17±12.36	101.63±13.99	0.275	0.792
VCR	6.39±0.59[a]	5.79±0.67[b]	5.43±0.71[b]	6.47±1.05[a]	0.905	0.000

[a – b] Means with different superscripts within the same line diverge significantly (P<0.05), according to Duncan's test.
[1]VH, villus height; CD, crypt depth; VCR, villus-crypt rate.
[2] Data were analyzed using linear and quadratic regression models of SPSS.

Table 6. Meat Quality Analysis in Japanese Quails supplemented with dietary PCB.

Parameters[1]	PCB Levels (g/kg diet)				*Significance (P-value)*[2]	
	0	0.5	1.0	2.0	L	Q
pH, 1st Day	5.87±0.14	5.92±0.11	5.88±0.11	5.92±0.14	0.444	0.799
pH 15th Day	5.96±0.22	6.01±0.30	6.00±0.16	6.07±0.16	0.238	0.948
pH 30th Day	6.33±0.54	6.30±0.45	6.44±0.49	6.53±0.46	0.250	0.686
WHC (%)	59.21±2.95	60.03±1.78	59.61±5.47	60.80±2.89	0.348	0.857
MDA (nmol/L)	17.09±15.18	10.95±9.94	13.14±11.33	15.74±16.76	0.917	0.271
Luminosity (L)	34.44±2.99	36.14±3.54	35.06±3.48	36.18±2.93	0.329	0.752
Color a	6.51±1.99	6.85±2.53	6.99±2.43	6.15±1.80	0.748	0.360
Color b	5.80±1.96	5.56±1.58	5.35±1.72	5.26±2.71	0.492	0.898

[1]WHC, water holding capacity; MDA, malondialdehyde.
[2] Data were analyzed using linear and quadratic regression models of SPSS.

Discussion and Conclusion

It was reported that butyric acid-enhanced performance in livestock by improving the histomorphological structure of the intestines and increasing digestive enzyme secretions by stimulating primarily pancreas exocrine activity (1). In the present study, dietary PCB supplementation positively affected BW on the 21st day and BWG between 1-21 days, yet no effect was observed in BW on the 42nd day, BWG between 22-42 and 1-42 days, FI and FCR values statistically. Similarly, Panda et al. (23) suggested that 0.4% butyrate supplementation in broilers' diet had the best BWG results in 0-3 weeks period. Additionally, sodium butyrate in Japanese quail diets boosted live BW in 21 days and BWG between 1-21 days was mentioned by Elnesr et al. (9). The improvement of BW and BWG in the early period of the current trial may be due to the acidifying properties of organic acids in the digestive systems of young poultry whose endogenous acid production is insufficient (3).

Another important finding of this research was improved HCY in Japanese quails with dietary PCB supplementation. Similar to our findings, Abd El-Wahab et al. (1) reported that dressed carcass was greater in the groups that received dietary calcium butyrate in Japanese quails. Equivalently, several researchers also found an additive effect of butyrate on carcass yield in broilers (19, 23). Butyric acid can involve carcass characteristics through increasing performance by improving intestinal absorption capacity and enhanced microflora (19). Mátis et al. (19) also reported butyrate also affect positively muscle development and stimulate insulin. In the current study, butyrate addition to quail diets enhanced relative heart weight linearly. Contrary to our findings, no effect on heart weight was observed in butyrate supplementation studies in broilers (11, 19) and quails (1, 26). A higher heart weight ratio to body weight is related to elevated blood circulation to secure oxygen supply for increased organ weights and metabolism (21). In the current study, increased HCY might also improve relative heart weights in the groups fed with PCB-supplemented diets too.

Blood biochemical parameters in poultry could be used as an important indicator of the animals' current physiological status and nutritional condition. BUN level in blood serum was lower in groups fed with PCB in our study. Butyrate also reduced BUN concentration in broilers (15) and rats with renal ischemia-reperfusion injury (30). Higher BUN values are correlated with tissue destruction in kidneys due to the losing filtration ability of damaged glomerulus cells (28). Butyric acid is reported as a therapeutic agent to prevent renal dysfunctions because of its antioxidant, anti-inflammatory, and antiapoptotic effects (30). The addition of butyrate to animal diets is considered helpful in reducing cholesterol values in blood by regulating gene expression to decrease lipid bioactivities in the jejunum (27). In this study, total cholesterol and LDL levels were lower in the groups fed with PCB-supplemented diets. Yin et al. (27) also revealed that butyrate glyceride supplementation in broiler diets decreased total cholesterol, triglyceride, and LDL values in blood statistically. Similarly, cholesterol content was decreased with fed butyrate in quails (9) and broilers (3, 15, 29).

We hypothesized PCB could enhance folate absorption either by improving intestinal histomorphology or microflora, however, no significant alteration was observed both for FA and homocysteine levels in blood serum in the current study. Although no study was found on the effect of dietary butyrate supplementation on blood homocysteine levels, several research studies have been conducted on different SCFA responses. Similar to our findings, Gheflati et al. (10) expressed that dietary apple vinegar, rich with acetic acid, consumption didn't differ in homocysteine content in the blood of patients with type-2 diabetes. Thus, Lamarre et al. (16) described vitamin B_{12} and folate deficiency caused to reduce methionine synthase activity and increase formate levels in rats. Hence, further studies are needed to assess the effect of butyrate on homocysteine concentration and FA production.

In the present study, the data on jejunum histomorphology showed that the supplement of PCB didn't differ in crypt depth on the 42nd day of the trial. It was also observed augmenting the amount of PCB in quail diets affected VH value negatively. Furthermore, the control group had a better VCR than the birds fed with 0.5 and 1.0 g/kg PCB supplemented diet and almost equal to the ones supplemented with 2.0g/kg PCB. Consistent with our results, different researchers reported no effect of butyrate on Jejunum histomorphology in broilers (12, 13, 17). Contrary, different studies indicate that dietary butyrate implementation has a beneficial effect on intestinal histomorphology in broilers (14, 23) and quails (9, 26). Adil et al. (2) indicated broilers fed with 2% and 3% butyric acid improved villus height in duodenum and jejunum yet did not differ statistically in ileum and crypt depth in all three parts of intestines. Despite the other researchers, Baltić et al. (6) mentioned medium chained fatty acids affect negatively villus height in the ileum. Antongiovanni et al. (4) pointed out dietary butyric acid supplementation depressed villus length in the jejunum and ileum of broilers. Another study conducted on broiler chickens showed that the birds fed with coarse ground diets had better villus height than the ones who received a fine ground diet even though, both groups were supplemented with BA in the experiment period (24). Divergences between different reports might be related to not only the amount of butyrate supplementation in the

diet, but also to slaughtering age, feed particle size in diet, enzyme supplementation, and intestinal part of the birds.

In our study, no significant effect of PCB was found on the oxidation process both in meat and blood serum. Similar to our findings, a trial in broiler chicken showed that coated sodium butyrate addition to birds' diet didn't significantly affect MDA values in broiler breast meat (11). A previous study in grass carp showed that dietary butyrate supplementation didn't significantly differ MDA and TAC values in hepatopancreas (18). Contrarily, several studies indicated MDA levels were depressed by dietary butyrate addition in broilers (12, 29) and quails (8). Liu et al. (18) stated indirect antioxidant effect of sodium butyrate depended on the supplement and was not sensitive in other tissues than the intestines which might be a possible explanation for our situation. Furthermore, WHC, meat pH, and meat LAB values weren't influenced by increasing amounts of PCB in the current trial. Meat quality could be associated with the antioxidant functions of butyric acid (29). The reason for the absence of difference in pH, color, and WHC values of the breast meat might be attributed to the fact that there is also no disparity in antioxidant levels in both meat and blood serum in our results.

According to our results for the present trial, it could be advised dietary PCB supplementation in Japanese quails improve body weight and body weight gain first half of the trial as well as HCY, relative heart weight, and reduce total cholesterol and HDL values in blood serum. Despite the majority of the other research studies, we couldn't find enhancing effect of PCB on jejunum histomorphology. In general, the results indicate that PCB at the dosage of 2.0 g/kg in quail feeds could be recommended to show butyric acid's positive impact on body weight, body weight gain, and carcass yield, especially for the first 21 days of the growing period.

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Author Contributions

Experimental design was determined by EG. Performance was recorded by EG and YC. Carcass parameters were established by EG and AGB. Jejunum histomorphology process was conducted by AGB. NHA established biochemical analysis. Chemical analysis of the quails' feed was carried out by KK. Statistical analysis was performed by EG. EG also wrote the first draft of manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethical Statement

The design of the experiment was approved by the local ethical committee of the Faculty of Agriculture in Selçuk University (Protocol No: 2019-001).

Animal Welfare

The authors confirm that they have adhered to ARRIVE Guidelines to protect animals used for scientific purposes.

Conflict of Interest

The authors declare that they have no competing interests.

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