Influence of vitamin B_{12} and Cobalt on growth of broiler chickens and Pekin ducks

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Summary

The effects of dietary vitamin B_{12} and cobalt supplementation on feed intake, growth performance, feed-to-gain ratio, carcass composition, and nutrient content of breast meat of ducks were investigated in broilers and Pekin ducks. 768 male chickens and 384 male ducks were allocated to 8 dietary treatment groups (0/10/20/40 µg vitamin B_{12}, 0.65 mg Co, 0.65 mg Co + 10 µg B_{12}, 0.65 mg Co + 20 µg B_{12}, 0.65 mg Co + 40 µg B_{12}) and fed for 35 or 49 days. The daily feed intake increased significantly from 76.3 to 81.3 g, the daily weight gain from 52.3 to 56.1 g, the final body weight from 1874 to 2007 g per broiler by raising the B_{12} concentration from 0 to 40 µg/kg. In the same way the supplementation of 0.65 mg Co improved the feed intake and thus the development of broilers. The feed-to-gain ratio was only affected in the first two weeks under higher B_{12} and B_{12} x Co concentration in the feed. The statistical evaluation of the single effects of vitamin B_{12} and Co and the combined effect of vitamin B_{12} + Co on performance of ducks could not demonstrate on daily feed intake, body weight gain, and final body weight. The feed conversion was negatively affected by supplementation of Co. An increased supply for the animals with vitamin B_{12} or Co induced a higher yield of breast meat by supplementation of 20 µg B_{12} and a higher percentage of breast meat and legs when adding on 0.65 mg Co. In the fresh breast matter of ducks was significantly higher water content and decreased protein content of the 0.65 mg Co-Group compared to 0.65 mg Co + 40 µg B_{12}-Group. The results allow the conclusion, that 20 µg of vitamin B_{12} per kg feed meet the requirements of growing chickens and ducks for fattening. An additional supplementation of Co to feed does not have additional advantages for the birds.

Keywords: vitamin B_{12}, Cobalt, growth performance, broiler, Pekin duck

Zusammenfassung

Einfluss von Vitamin B_{12} und Kobalt auf das Wachstum von Broiler und Pekingente

Der Einfluss der Supplementierung von Vitamin B_{12} und Kobalt auf Futteraufnahme, Wachstum, Futteraufwand, Schlachtkörperzusammensetzung und Gehalt an Nährstoffen im Entenbrustmuskel wurde untersucht. In den zwei Versuchen über 35 bzw. 49 Tagen wurden 768 männliche Broilerküken und 384 männliche Pekingenten in 8 Versuchsgruppen (0/10/20/40 µg B_{12}, 0.65 mg Co, 0.65 mg Co + 10 µg B_{12}, 0.65 mg Co + 20 µg B_{12}, 0.65 mg Co + 40 µg B_{12}) eingeteilt. Die Erhöhung des Vitamin B_{12} Gehaltes im Broilerfutter erhöhte statistisch gesichert die tägliche Futteraufnahme von 76,3 auf 81,3 g, die tägliche Lebendmassezunahme von 52,3 auf 56,1 und die Mastendmasse von 1874 g auf 2007. Die Supplementierung von 0,65 mg Co verbesserte die Futteraufnahme und Entwicklung der Broiler. Die bessere Entwicklung der Broiler mit Vitamin B_{12} im Futter führte zu einem höheren Brustfleischertrag und Abdominalfettgehalt im Schlachtkörper. Die Supplementierung von B_{12} oder Co bzw. B_{12} + Co zum Entenmastfutter hatte keinen statistisch gesicherten Einfluss auf Futteraufnahme, tägliche Lebendmassezunahme und Mastendmasse. Der Futteraufwand war gesichert schlechter nach Co Supplementierung ins Futter. Die Supplementierung von 20 µg B_{12} oder 0,65 mg Co erhöhte gesichert den Brustfleischertrag bei den Enten. Die Analyse des frischen Entenbrustfleisches ergab einen gesichert höheren Gehalt an Wasser und niedrigeren Proteingehalt im Fleisch der Gruppe mit 0,65 mg Co im Futter im Vergleich zur Gruppe mit 40 µg B_{12} + 0,65 mg Co. Die Ergebnisse lassen die Schlussfolgerung zu, dass 20 µg Vitamin B_{12} pro kg Futter den Bedarf von Broiler und Pekingente decken und eine zusätzliche Co Supplementierung keinen additiven Einfluss hat.

Schlüsselworte: Vitamin B_{12}, Kobalt, Wachstum, Broiler, Pekingente

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Vitamin B_{12} is the most recently discovered vitamin (West, 1948) with the lowest concentration of vitamins needed to meet the requirement of animals. This vitamin belongs to a specific group of Cobalt (Co)-containing corrinoids with biological activity in humans and animals. The term vitamin B_{12} is restricted to the recommended biochemical nomenclature for the form of cobalamin. Cobalamin does not occur in plants, it is synthesized in nature by certain bacteria, fungi and algae (Green, 2005). Microbes in the rumen of ruminants incorporate Co into a corrin ring to form vitamin B_{12}. Vitamin B_{12} is an essential component of several enzyme systems that carry out a number of very basic metabolic functions in the animal's body (McDowell, 1989). This vitamin plays a central role in normal functions of the brain and the nervous system, in the homocystein metabolism, in the blood function, energy metabolism, cell division and functions of the immune system (EFSA, 2009a; 2010). 10 µg per kg feed are indicated by the NRC (1994), and 9 µg B_{12} per kg by the GfE (1999) as the requirement for broiler chickens and Pekin ducks.

There is no evidence that monogastric animals (pigs and poultry) require Cobalt (Co) other than through vitamin B_{12}. Consequently, there is no need for any Co supplementation to the feed for these animals (EFSA, 2009b). Although Co is not necessary for nutrition of broiler chickens, it is often added into the vitamin-mineral premix. Poultry obtain their B_{12} either preformed in feed or indirectly by ingesting faeces.

The objective of this study was to determine the effect of a Vitamin B_{12}-free diet supplemented with Vitamin B_{12} or/and Cobalt on broiler and Pekin duck performance.

Material and methods

In Trial 1 a total number of 768 one-day old male chickens for fattening (Ross 308) was randomly distributed in treatments with 12 chickens per pen and 8 pens per group (Table 1). The duration of the trial was 35 days. Body weight was recorded for each broiler individually at days 14, 21 and 35 of age. Feed was weighed back on a pen-basis weekly. One bird per pen, representing the mean body weight of broilers of this pen, was slaughtered at the end of the trial (8 broilers per group) to determine carcass composition. Weights of total breast meat (without skin), complete right leg, liver, heart, gizzard, spleen and sum of abdominal and viscera fat were individually recorded. All parts were expressed as percentage of body weight.

In Trial 2 a total number of 384 male one-day old Pekin ducks was randomly distributed in treatments with 6 ducks per pen and 8 pens per group (Table 1). The duration of the trial was 49 days. Body weight was recorded for each duck individually at days 21 and 49 of age. Feed was weighed back on a pen-basis weekly. One bird per pen, representing the mean body weight of ducks of this pen, was slaughtered at the end of the trial (8 ducks per group) to determine carcass composition. Weights of total breast meat (without skin), complete right leg, liver, heart, gizzard, spleen and sum of abdominal and viscera fat were individually recorded. Breast meat of slaughtered ducks of Groups 1, 4, 5 and 8 was analyzed for moisture and intramuscular fat content with Near Infrared Transmission Spectroscopy (NIT) according to percentages of protein were calculated (Köhler et al., 1995).

Table 1:
Trial design

Group	B_{12}, µg/kg	Co, mg/kg
1	0	0
2	10	0
3	20	0
4	40	0
5	0	0.65
6	10	0.65
7	20	0.65
8	40	0.65

Pelleted feed (Table 2) was provided for ad libitum consumption as a one phase feed for broilers and second-phase feed (starter feed: day 1 to 21, fattening feed: day 22 to 49) for Pekin ducks. The basal diet was not supplemented with vitamin B_{12} and contained Co only from natural sources (wheat, corn, soya bean meal). The microbiological analyses (LUFA Speyer, LUFA SP 22013) of the diet yielded a value of 4 µg B_{12} per kg. This value resulted from microbiological contamination of the feedstuffs. The basal diet was supplemented with 0/10/20/40 µg B_{12} per kg, 0.65 mg Co, 0.65 mg Co + 10 µg B_{12}, 0.65 mg Co + 20 µg B_{12} and 0.65 mg Co + 40 µg B_{12} per kg (Table 1).

Data from the two trials were analyzed by a two-way ANOVA: $y_{ijk} = \mu + V_i + C_j + VC_{ij} + e_{ijk}$, with yijk = observation, µ = general mean, Vi = vitamin B_{12} (0, 10, 20 and 40 µg), Cj = Cobalt (0 and 0.65 mg), interaction VCij and eijk = error term (random). Multiple comparisons of means were carried out using the Student-Newman-Keuls Test ($P \leq 0.05$). The statistical analyses were performed by the SAS software package (Version 9.1).

Table 2:

Ingredient composition, analysed and calculated nutrients of the diets (g/kg)

Ingredient Age of days	Broiler 1 - 35	Pekin duck 1 - 21	 22 - 49
Wheat	150.0	150.0	400.0
Corn	378.7	480.7	316.3
Soya bean meal	386.4	299.8	212.8
Soya oil	49.8	24.9	29.4
Di-calcium-phosphate	10.0	19.6	17.6
Calcium carbonate	10.5	7.8	6.7
Sodium chloride	3.2	3.4	3.5
DL-Methionine	2.8	2.0	2.1
L-Lysine-HCl	1.7	1.6	1.6
L-Threonine	-	0.2	-
Premix[1)]	10.0	10.0	10.0
Vitamin B_{12}[2)], µg/kg	0/10/20/40	0/10/20/40	0/10/20/40
Co[2)], mg/kg	0/0.65	0/0.65	0/0.65
Dry matter[3)]	887	878	882
Crude protein[3)]	202	199	172
ME, MJ/kg[4)]	13.16	12.37	12.62
Lysine[5)]	12.5	11.5	9.5
Methionine + Cystine[5)]	9.6	8.5	8.0
Cobalt, µg/kg[6)]	51	48	39
Vitamin B_{12}[7)], µg/kg	4.0	4.0	4.0

[1)] Vitamin – mineral premix provided per kg of diet: vitamin A, 12000 IE; vitamin D3 3500 IE; tocopherol, 40 mg; menadion, 4.5 mg; thiamine, 2.5 mg; riboflavin, 8 mg; pyridoxine, 6 mg; nicotinic acid, 45 mg; pantothenic acid, 15 mg; folic acid, 1.2 mg; biotin, 50 µg; choline chloride, 550 mg; Fe, 32 mg; Cu, 12 mg; Zn, 80 mg; Mn, 100 mg; Se, 0.4 mg; I, 1.6 mg
[2)] Cyanocobalamin supplements – 0.1 % vitamin B12; Cobalt carbonat – 5 % Co
[3)] Analyzed values
[4)] Calculated values (WPSA, 1985)
[5)] Calculated values
[6)] Calculated values (Souci et al., 2008)
7) Analyzed values –LUFA SP 22013

Results

Trial 1 – Broiler chicken

The statistical evaluation of the single effect of vitamin B_{12} and Co and the combined effect of vitamin B_{12} + Co on performance of broilers demonstrated a high dependence ($P < 0.05$) of the vitamin B_{12} or/and Co concentration in the broiler feed on the daily feed intake, the body weight gain, and final body weight. The daily feed intake increased significantly from 76.3 g to 81.3 g, the daily weight gain from 52.3 g to 56.1 g, the final body weight from 1874 g to 2007 g per broiler with raising the B_{12} concentration from 0 to 40 µg per kg feed (Table 3, 4, 5). In the same way the supplementation of 0.65 mg Co per kg diet improved ($P < 0.05$) the feed intake and thus the development of broiler chickens (Table 6). The feed-to-gain ratio was only affected in the first two weeks of the raised B_{12} and B_{12} x Co concentrations in the feed (Table 4). An improved supply of vitamin B_{12} for the animals led to a higher yield of breast meat ($P < 0.05$), but also a higher mass of viscera fat in broilers (Table 7).

Trial 2 – Pekin ducks

The statistical evaluation of the single effects of vitamin B_{12} and Co and the combined effect of vitamin B_{12} + Co on performance of ducks could not demonstrate dependence ($P > 0.05$) of vitamin B_{12} or/and Co concentration in the feed on the daily feed intake, the body weight gain, and final body weight (Table 8, 9, 10). The feed-to-gain ratio was negatively affected ($P \leq 0.05$) by supplementation of Co in the feed (Table 9, 11). An increased supply with vitamin B_{12} or Co resulted in a higher yield of breast meat

Table 3:

Performance of broilers – Feed intake, body weight gain (Mean, SD, P-value)

Treatments		Feed intake, g/broiler/day, age of days				Body weight gain, g/broiler/day, age of days			
B_{12}, µg/kg	Co, mg/kg	1 – 14	15 – 21	22 – 35	1 – 35	1 – 14	15 – 21	22 – 35	1 – 35
0	0	24.7 ± 1.4	58.7 ± 3.1	122.0 ±7.7	70.3 ± 4.2	18.1 ± 0.8	42.0 ± 3.9	80.5 ± 5.4	47.8 ± 2.5
10	0	26.1 ± 2.0	67.5 ± 4.6	131.9 ±7.6	76.7 ± 4.3	20.6 ± 1.2	46.9 ± 2.9	88.0 ± 4.3	52.8 ± 2.5
20	0	28.0 ± 1.5	70.2 ± 5.7	138.4 ± 8.7	80.4 ± 4.8	21.6 ± 1.4	49.8 ± 4.0	92.0 ± 5.2	55.4 ± 3.1
40	0	28.0 ± 1.0	71.5 ± 2.8	138.8 ± 4.3	81.0 ± 2.3	21.4 ± 0.7	50.9 ± 1.8	93.4 ± 3.0	56.0 ± 1.5
0	0.65	29.0 ± 1.3	73.1 ± 4.6	140.5 ± 6.0	82.2 ± 3.7	21.9 ± 1.3	52.0 ± 4.4	94.0 ± 5.0	56.8 ± 3.1
10	0.65	27.6 ± 0.9	69.3 ± 3.3	134.8 ± 7.9	78.8 ± 4.0	20.8 ± 0.9	47.3 ± 2.8	89.6 ± 4.4	53.6 ± 2.4
20	0.65	27.1 ± 1.5	69.6 ± 3.6	136.4 ± 5.1	79.2 ± 3.2	20.7 ± 1.1	48.1 ± 1.9	91.2 ± 3.4	54.4 ± 1.9
40	0.65	27.6 ± 1.3	71.7 ± 4.3	140.4 ± 7.0	81.5 ± 3.9	21.2 ± 1.1	51.2 ± 3.5	93.6 ± 4.3	56.2 ± 2.3
ANOVA, P-value									
B_{12}		0.125	0.002	0.005	0.003	0.006	0.006	0.003	0.003
Co		< 0.004	0.001	0.004	0.001	0.009	0.009	0.008	0.008
B_{12} x Co		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 4:

Performance of broilers – Feed-to-gain-ratio, body weight (Mean, SD, P-value)

Treatments		Feed-to-gain ratio, kg/kg, age of days				Body weight, g/broiler, age of days			
B_{12}, µg/kg	Co, mg/kg	1 – 14	15 – 21	22 – 35	1 – 35	1	14	21	35
0	0	1.37 ± 0.06	1.40 ± 0.11	1.52 ± 0.05	1.47 ± 0.02	44 ± 1	297 ± 10	591 ± 31	1718 ± 88
10	0	1.27 ± 0.06	1.44 ± 0.04	1.50 ± 0.03	1.45 ± 0.02	44 ± 1	332 ± 17	661 ± 35	1893 ± 87
20	0	1.29 ± 0.04	1.41 ± 0.04	1.50 ± 0.42	1.45 ± 0.03	44 ± 1	347 ± 19	696 ± 44	1983 ± 109
40	0	1.31 ± 0.03	1.41 ± 0.04	1.49 ± 0.04	1.44 ± 0.02	44 ± 1	343 ± 11	699 ± 21	2006 ± 53
0	0.65	1.32 ± 0.03	1.41 ± 0.06	1.50 ± 0.04	1.45 ± 0.03	44 ± 1	351 ± 18	715 ± 47	2031 ± 108
10	0.65	1.33 ± 0.04	1.46 ± 0.04	1.50 ± 0.03	1.47 ± 0.02	44 ± 1	335 ± 12	666 ± 30	1921 ± 84
20	0.65	1.31 ± 0.06	1.45 ± 0.03	1.50 ± 0.03	1.46 ± 0.04	43 ± 1	334 ± 15	670 ± 26	1947 ± 68
40	0.65	1.30 ± 0.02	1.40 ± 0.05	1.50 ± 0.03	1.45 ± 0.02	43 ± 1	340 ± 17	698 ± 35	2008 ± 81
ANOVA, P-value									
B_{12}		0.018	0.088	0.845	0.508	-	0.007	0.002	< 0.001
Co		0.822	0.261	0.768	0.731	-	0.100	< 0.004	< 0.001
B_{12} x Co		0.018	0.718	0.595	0.205	-	< 0.001	< 0.001	< 0.001

($P \leq 0.05$) by supplementation of 20 µg B_{12} and a higher yield of breast meat and percentage of breast meat and legs of 0.65 mg Co per kg diet (Table 11, 12).

Analysis of the nutrients in the fresh breast matter (Table 13) caused a significantly higher water content and decreased protein content in breast meat of the 0.65 mg Co-Group compared to 0.65 mg Co + 40 µg B_{12}-Group.

Table 5:

Influence of vitamin B_{12} on performance of broilers (Mean, day 1 to 35)

Vitamin B_{12}, µg/kg	0	10	20	40
Feed intake, g/broiler/day	76.3 c	77.8 bc	79.8 ab	81.3 a
Body weight gain, g/broiler/day	52.3 c	53.2 bc	54.9 ab	56.1 a
Final body weight, g	1874 c	1907 bc	1965 ab	2007 a

a; b; c; – Means with different letters differ significantly within rows

Table 6:

Influence of Co on performance of broilers (Mean, day 1 to 35)

Co, mg/kg	0	0.65
Feed intake, g/broiler/day	77.1 b	80.4 a
Body weight gain, g/broiler/day	53.0 b	55.2 a
Final body weight, g	1900 b	1977 a

a; b; – Means with different letters differ significantly within rows

Discussion

The effect of Vitamin B_{12} and Cobalt on growth and body composition was studied in broiler chickens and Pekin ducks. Data on the requirement of Vitamin B_{12} in chickens for fattening and ducks are limited.

In the present studies the main impact of prolonged vitamin B_{12} deficiency in chickens for fattening was a reduced daily feed intake. As a result the feed intake of these broilers (supplementation of 0 µg B_{12} per kg feed) was 6 % and final body weight was 7 % less compared to birds with 40 µg B_{12} per kg diet. In the trial with Pekin ducks no differences in the feed intake and body weight gain were established between the vitamin B_{12}-deficient group and the vitamin B_{12}-supplemented groups. But the depletion of vitamin B_{12} decreased the breast meat yield in ducks. The breast meat yield was 12 % less in the control group (0 µg B_{12} per kg feed) compared to ducks with 20 µg B_{12} per kg diet at the age of 49 days.

The dietary needs for vitamin B_{12} for poultry species are low and the NRC (1984) recommended to decrease the vitamin B_{12} supplementation from 9 to 3 µg B_{12} per kg feed (dry matter) as Leghorn chicks progress between 0 to 6 and 6 to 12 weeks of age. But there is no evidence to justify this scaling to body weight or age. Pair-feeding broiler studies of Looi and Renner (1974) demonstrated that vitamin B_{12} stimulated growth of chickens fed either carbohydrate-containing or carbohydrate-free diets by stimulating feed intake and not by increasing utilization of either protein or energy. These results showed that the addition of 20 µg B_{12} per kg diet caused a significant increase in the growth of chicks (Table 5) and no further significant increase was observed with the addition of higher levels

Table 7:

Carcass (% of body weight), carcass composition (% of carcass weight) and muscle and organ weight (g) of broilers (n = 8) (Mean, SD, P-value)

B_{12}, µg/kg	Co, mg/kg	Body weight, g	Carcase, %	Breast skin, %	Breast meat, g	Breast meat, %	Legs, g	Legs, %	Liver, g	Heart, g	Gizzard, g	Spleen, g	Fat, g	Fat, %
0	0	1831 ± 71	64.5 ± 1.0	1.3 ± 0.3	214 ± 18	11.6 ± 0.5	362 ± 17	19.8 ± 1.0	40.6 ± 2.7	12.4 ± 1.6	39.9 ± 3.5	1.8 ± 0.4	20.1 ± 3.4	1.1 ± 0.2
10	0	1958 ± 56	64.6 ± 1.6	1.2 ± 0.2	255 ± 21	13.0 ± 1.0	373 ± 25	19.0 ± 1.1	42.8 ± 5.9	12.2 ± 1.1	33.1 ± 6.6	1.7 ± 0.4	29.0 ± 6.3	1.5 ± 0.3
20	0	1958 ± 20	64.0 ± 1.5	1.2 ± 0.2	221 ± 28	11.3 ± 1.4	380 ± 22	19.4 ± 1.0	43.2 ± 3.2	12.8 ± 1.2	33.6 ± 1.9	2.1 ± 0.5	28.0 ± 6.3	1.4 ± 0.3
40	0	1979 ± 96	64.7 ± 0.9	1.1 ± 0.2	244 ± 21	12.3 ± 0.9	386 ± 20	19.5 ± 0.9	43.3 ± 2.3	12.6 ± 1.2	33.1 ± 7.1	2.4 ± 0.6	29.5 ± 2.4	1.5 ± 0.1
0	0.65	1981 ± 36	64.7 ± 3.6	1.1 ± 0.1	259 ± 31	13.1 ± 1.5	384 ± 26	19.4 ± 1.3	41.4 ± 3.4	11.8 ± 2.0	28.8 ± 4.6	2.0 ± 0.6	20.2 ± 5.9	1.0 ± 0.3
10	0.65	1958 ± 85	64.6 ± 2.4	1.1 ± 0.2	244 ± 21	12.5 ± 0.8	383 ± 30	19.5 ± 1.2	42.9 ± 2.5	12.5 ± 0.9	36.2 ± 9.1	2.1 ± 0.3	25.6 ± 7.5	1.3 ± 0.4
20	0.65	1944 ± 51	63.9 ± 1.9	1.3 ± 0.2	229 ± 34	11.8 ± 1.6	384 ± 16	19.8 ± 0.9	43.8 ± 4.8	12.9 ± 2.0	33.1 ± 5.6	2.0 ± 0.5	23.7 ± 4.8	1.2 ± 0.2
40	0.65	1949 ± 62	65.1 ± 1.4	1.1 ± 0.1	246 ± 23	12.6 ± 1.2	395 ± 24	20.2 ± 1.0	41.7 ± 2.6	13.0 ± 0.6	30.6 ± 6.2	1.6 ± 0.7	23.7 ± 5.3	1.2 ± 0.3
ANOVA, P-value														
B_{12}		0.055	0.574	0.199	0.043	0.004	0.177	0.495	0.270	0.380	0.391	0.734	0.002	0.004
Co		0.110	0.695	0.233	0.081	0.168	0.060	0.279	1.000	0.993	0.413	0.427	0.018	0.010
B_{12} x Co		< 0.001	0.985	0.025	0.018	0.151	0.729	0.495	0.774	0.718	0.272	0.011	0.490	0.799

Table 8:

Performance of ducks – Feed intake, daily weight gain (Mean, SD, P-value)

Treatments		Feed intake, g/duck/day, age of days			Daily weight gain, g/duck/day, age of days		
B_{12} µg/kg	Co, mg/kg	1 – 21	22 – 49	1 – 49	1 – 21	22 – 49	1 – 49
0	0	116.0 ± 4.1	256.1 ± 8.0	193.0 ± 4.1	69.2 ± 1.7	92.0 ± 2.4	81.8 ± 1.3
10	0	116.4 ± 5.6	248.8 ± 12.9	189.2 ± 9.3	69.7 ± 3.3	89.9 ± 5.3	80.9 ± 4.0
20	0	116.2 ± 8.8	246.1 ± 23.8	187.7 ± 17.2	69.7 ± 3.6	90.8 ± 4.9	81.4 ± 3.8
40	0	113.7 ± 5.4	250.4 ± 12.1	188.6 ± 8.9	69.5 ± 2.0	90.1 ± 6.0	80.9 ± 3.6
0	65	115.4 ± 5.3	257.4 ± 12.5	194.0 ± 8.2	69.3 ± 2.6	89.6 ± 4.4	80.5 ± 3.0
10	65	117.5 ± 4.3	251.5 ± 19.2	191.6 ± 11.3	70.5 ± 2.8	87.7 ± 7.0	80.1 ± 4.6
20	65	114.7 ± 5.5	253.6 ± 14.2	191.0 ± 9.2	70.3 ± 2.4	88.8 ± 3.2	80.5 ± 2.3
40	65	117.0 ± 3.8	250.6 ± 12.9	190.7 ± 8.3	71.1 ± 2.3	87.1 ± 5.3	80.0 ± 3.6
ANOVA, P-value							
B_{12}		0.817	0.523	0.647	0.724	0.584	0.896
Co		0.708	0.446	0.396	0.265	0.062	0.252
B_{12} x Co		0.602	0.906	0.990	0.880	0.994	0.998

of vitamin B_{12}. Patel and McGinnis (1980) found that vitamin B_{12} is important in the energy metabolism. In a study with White Leghorn chicks the growth and efficiency of feed utilization were depressed upon addition of 10 and 20 % fat unless the diet contained adequate vitamin B_{12}. Isoenergetic substitution of glucose instead of fat also depressed growth unless B_{12} was added. Higher protein content in the diet increases the need for vitamin B_{12}.

Leeson and Summers (2001) summarized that a deficiency of B_{12} in growing chickens results in reduced weight gain and feed intake, along with poor feathering and nervous disorders. While a deficiency may lead to perosis, this

Table 9:
Performance of ducks – Feed-to-gain-ratio, body weight (Mean, SD, P-value)

Treatments		Feed-to-gain ratio, kg/kg, age of days			Body weight, g/duck, age of days		
B_{12}, µg/kg	Co, mg/kg	1 – 21	22 – 49	1 – 49	1	21	49
0	0	1.68 ± 0.04	2.78 ± 0.09	2.36 ± 0.04	56 ± 3	1510 ± 32	3902 ± 60
10	0	1.67 ± 0.02	2.77 ± 0.15	2.34 ± 0.10	56 ± 2	1519 ± 68	3856 ± 186
20	0	1.66 ± 0.06	2.71 ± 0.20	2.30 ± 0.14	57 ± 2	1522 ± 78	3884 ± 181
40	0	1.64 ± 0.05	2.78 ± 0.11	2.33 ± 0.08	56 ± 2	1515 ± 42	3858 ± 171
0	65	1.67 ± 0.04	2.88 ± 0.18	2.41 ± 0.12	56 ± 1	1512 ± 55	3841 ± 142
10	65	1.67 ± 0.03	2.88 ± 0.27	2.40 ± 0.16	55 ± 1	1536 ± 58	3816 ± 215
20	65	1.63 ± 0.05	2.86 ± 0.16	2.37 ± 0.11	58 ± 2	1532 ± 51	3842 ± 108
40	65	1.65 ± 0.04	2.88 ± 0.14	2.39 ± 0.10	54 ± 2	1547 ± 48	3812 ± 173
ANOVA, P-value							
B_{12}		0.122	0.819	0.688	-	0.744	0.886
Co		0.368	0.013	0.042	-	0.288	0.247
B_{12} x Co		0.465	0.965	0.996	-	0.897	0.998

Table 10:
Influence of vitamin B_{12} on performance of ducks (Mean, day 1 to 49)

B_{12}, µg/kg	0	10	20	40
Feed intake, g/duck/day	193.5	190.4	189.6	189.4
Body weight gain, g/duck/day	90.8	88.8	89.8	88.6
Feed to gain ratio, kg/kg	2.38	2.37	2.34	2.36
Final body weight, g	3872	3836	3863	3835
Breast meat, g	201.8 b	211.8 ab	228.8 a	224.3 ab

a; b; – Means with different letters differ significantly within rows

Table 11:
Influence of Co on performance of ducks (Mean, day 1 to 49)

Co, mg/kg	0	0.65
Feed intake, g/duck/day	189.6	191.8
Body weight gain, g/duck/day	81.2	80.3
Feed to gain ratio, kg/kg	2.33 b	2.39 a
Final body weight, g	3875	3828
Breast meat, g	209.5 b	224.2 a
Breast meat, %	10.8 b	11.7 a
Legs, %	12.6 b	13.0 a

a; b; – Means with different letters differ significantly within rows

is probably a secondary effect due to a dietary deficiency of methionine, choline or betaine as sources of methyl groups. Further clinical signs reported in poultry are anemia, gizzard erosion, and fatty infiltration of heart, liver and kidneys.

Vitamin B_{12} is retained in the liver for a long time after the feeding of Vitamin B_{12}-deficient diets has begun. For example, two to five months may be needed to deplete hens of vitamin B_{12} stores to such an extent that progeny will hatch with low vitamin B_{12} reserves (Scott et al., 1982). On the question of vitamin B_{12} storage in the egg Robel (1983) established that changes in vitamin levels (also in vitamin B_{12}) deposited in the egg are related to the aging process of the turkey breeder hen. Squires and Naber (1992) concluded from the results of a study of vitamin profiles of eggs – which concentrations of vitamin B_{12} between 1.3 and 2.9 µg/100 g egg yolks are found, and for this reason, 8 µg vitamin B_{12} per kg diet appeared to be needed to support maximum hatchability and egg weight. In the present studies chickens and ducks originated from parent flocks with feeding according nutrient requirements of breeder hens and ducks. Therefore it can be assumed that the storage of vitamin B_{12} into the egg yolk was stabilized and the freshly hatched chickens and ducks had an optimum B_{12} depot in the liver and in last part of the yolk sac.

Surprising in the present studies was that supplementation of Co only (without supplementation of vitamin B_{12} in the diets) did not significantly decrease feed intake, and so the final body weight and the breast meat yield in growing

Table 12:

Carcass (% of body weight), carcass composition (% of carcass weight) and muscle and organ weight (g) of ducks (n = 8) (Mean, SD, P-value)

B_{12}, µg/kg	Co, mg/kg	Body weight, g	Carcase, %	Breast skin, %	Breast meat, g	Breast meat, %	Legs, g	Legs, %	Liver, g	Heart, g	Gizzard, g	Spleen, g	Fat, g	Fat %
0	0	3882 ± 121	67.5 ± 0.4	3.6 ± 0.6	377 ± 24	9.7 ± 0.5	497 ± 32	12.9 ± 1.0	93.0 ± 15.4	20.5 ± 1.6	124.6 ± 13.9	2.4 ± 0.4	35.1 ± 5.6	0.9 ± 0.2
10	0	3801 ± 262	66.9 ± 0.8	3.9 ± 1.2	402 ± 45	10.6 ± 1.0	482 ± 56	12.6 ± 0.9	84.2 ± 12.8	19.3 ± 2.3	116.4 ± 14.1	2.3 ± 0.4	37.0 ± 14.9	1.0 ± 0.3
20	0	3960 ± 173	67.3 ± 0.9	4.1 ± 0.6	460 ± 51	11.6 ± 1.3	496 ± 19	12.5 ± 0.6	87.2 ± 12.3	20.0 ± 1.6	126.0 ± 9.3	2.4 ± 0.6	35.9 ± 8.8	0.9 ± 0.2
40	0	3934 ± 150	68.0 ± 1.3	4.2 ± 1.0	432 ± 19	11.0 ± 0.5	484 ± 27	12.3 ± 0.9	85.7 ± 12.0	20.3 ± 1.8	122.2 ± 17.2	1.8 ± 0.6	34.5 ± 8.0	0.9 ± 0.2
0	0.65	3754 ± 217	67.4 ± 1.2	3.9 ± 0.5	428 ± 76	11.4 ± 1.5	480 ± 22	12.8 ± 0.6	84.7 ± 9.7	19.9 ± 2.7	114.8 ± 12.0	2.0 ± 0.6	28.4 ± 7.6	0.8 ± 0.2
10	0.65	3815 ± 311	68.2 ± 1.4	4.4 ± 0.9	445 ± 62	11.7 ± 1.3	516 ± 49	13.5 ± 0.9	75.2 ± 12.0	19.7 ± 1.4	125.6 ± 19.5	1.7 ± 0.6	37.8 ± 14.9	1.0 ± 0.4
20	0.65	3861 ± 100	68.0 ± 1.5	4.2 ± 0.8	455 ± 68	11.8 ± 1.8	516 ± 49	12.7 ± 0.5	78.9 ± 15.2	19.8 ± 1.3	121.1 ± 8.6	2.2 ± 0.5	36.0 ± 14.3	0.9 ± 0.4
40	0.65	3845 ± 155	68.5 ± 1.3	4.2 ± 0.9	465 ± 48	12.1 ± 1.0	497 ± 32	12.9 ± 0.6	87.0 ± 11.8	20.9 ± 2.1	119.6 ± 12.3	2.0 ± 0.6	35.6 ± 11.6	0.9 ± 0.3
ANOVA, P-value														
B_{12}		0.342	0.280	0.677	0.021	0.045	0.862	0.275	0.336	0.452	0.791	0.264	0.624	0.614
Co		0.162	0.052	0.385	0.025	0.002	0.484	0.052	0.104	0.903	0.675	0.051	0.636	0.825
B_{12} x Co		0.805	0.370	0.782	0.450	0.406	0.208	0.320	0.626	0.849	0.349	0.153	0.693	0.659

Table 13:

Content of water, protein and fat in the fresh matter of the breast meat of Pekin ducks (%) (n = 8) (Mean, SD)

Group	1 Control	4 40 µg B_{12}	5 0.65 mg Co	8 0.65 mg Co + 40 µg B_{12}
Water	76.6 ab ± 0.4	76.4 ab ± 0.3	76.8 a ± 0.5	75.9 b ± 0.6
Crude fat	1.2 ± 0.2	1.2 ± 0.1	1.2 ± 0.2	1.2 ± 0.1
Crude protein	22.2 ab ± 0.4	22.4 ab ± 0.3	22.0 b ± 0.8	22.8 a ± 0.5

a; b; – Means with different letters differ significantly within rows

chickens and ducks for fattening was identical to groups supplemented with vitamin B_{12} (10/20/40 µg vitamin B_{12} per kg diet). In studies with pigs it was observed that vitamin B_{12} – deficiency symptoms, including an accumulation of serum homocysteine, can be attenuated by Nickel and Co, although the mode of action seems to differ (Stangl et al., 2000). Previous studies found out that Co ions induce a series of metabolic changes in experimental animals. Co supplementation only improved homocysteine accretion in serum, whereas the vitamin B_{12} status remained completely unchanged (Goncharevskaia et al., 1985; Rosenberg and Kappas, 1989; Zhang et al., 1998). In this duck study the breast meat yield of the Co group was similar to groups supplemented with vitamin B_{12}, however the protein content of breast meat was decreased. This finding indicated that there is not an improvement of the vitamin B_{12} status and protein syntheses of the meat after supplementation of Co.

Furthermore it cannot be excluded that broilers, and notably ducks, in the present studies obtained a part of their vitamin B_{12} requirement more indirectly by ingesting faeces in the litter or with litter in the pens. The faeces bacterial flora is an important source of vitamins for coprophagic animals. The supplementation of Co to the broiler and duck diets supported the vitamin B_{12} synthesis of bacteria in the digestive tract.

It can be concluded from these observations that a supplementation of 20 µg vitamin B_{12} per kg broiler feed was sufficient to compensate the deficiencies on feed intake and growing performance. An exclusive supplementation of Co to the broiler feed improved the growing performance in a small scale. The supplementation of B_{12} plus Co did not have any additive effect on the performance of broilers.

The graded supplementation of vitamin B_{12} to the diet of Pekin ducks had no significant effect on growing performance, however, increased the breast meat yield particularly at 20 µg B_{12} per kg of feed. Supplementation of only Co or Co + B_{12} into the feed did not change feed intake and growing performance among the ducks either. Although the supplementation of 0.65 mg of Co/kg improved the breast meat yield, it leads to an unfavourable rise of the feed-to-gain ratio, however.

In summary the results allow the conclusion, that 20 µg vitamin B_{12} per kg feed meet the requirements of growing chickens and ducks for fattening. An additional supplementation of Co to feed does not have additional advantages for the birds.

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