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Effect of dietary protein and electrolyte balance on the performance of broiler chicks

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Summary

In this experiment the effect of the level of dietary protein and electrolyte balance (Na + K − Cl) on fattening, slaughtering performance and meat quality was tested. The trial consisted of four groups (four replicates per group) of 260 *Vedette* broiler chickens each. The chickens were reared on deep litter for 42 days. The electrolyte balance in feed mixture was 250, 350, 250, 350 meq/kg, while the protein content was 17, 17, 23 and 23 % respectively. The most important results are shown in the following table.

Table 1

Most important results

Protein	%	17	17	23	23
Electrolyte balance	meq/kg	250	350	250	350
Final weight	g	1666	1633	1832	1744
Feed efficiency		1.91	2.02	1.92	2.00
Abdominal fat	%	2.78	2.95	2.51	1.88
Fat in thigh muscle	%	18.10	18.90	17.50	15.70
Percentage in faeces:					
Dry matter[1]	%	37.10	23.90	49.10	31.70
Crude protein[2]	%	36.50	28.40	43.30	41.40
Ash[2]	%	20.30	23.10	17.90	18.90
Na[2]	%	0.93	1.25	0.56	0.86
K[2]	%	1.28	1.25	1.21	1.29

[1] data on fresh faeces basis
[2] data on dry matter basis

Fattening performance was clearly effected by protein level. Regarding fat percentage in the carcass and fat content of thigh muscle there was an effect of protein level and an interaction of protein level and electrolyte balance.

Nutrient and mineral content of faeces was influenced by protein level as well as by electrolyte balance and there was an interaction between those factors for crude protein and potassium. From the data presented here it can be concluded that highest performance was achieved with a diet containing 23 % protein and an electrolyte balance of 250 meq/kg.

Key-words: broiler, protein, electrolyte balance, performance, faeces.

Einfluß des Proteingehaltes und des Kationen : Anionen-Verhältnisses in der Ration auf die Leistung von Mastkücken

Zusammenfassung

Im Rahmen der vorliegenden Arbeit wurde der Einfluß eines unterschiedlichen Proteingehaltes und eines unterschiedlich hohen Kationen : Anionen-Verhältnisses (Na + K − Cl) auf die Mast- und Schlachtleistung sowie die Fleischbeschaffenheit von Mastkücken untersucht. Die Versuchsanlage bestand aus vier Gruppen mit vier Wiederholungen, wobei jede Gruppe 260 *Vedette*-Kücken umfaßte. Die Tiere wurden in Bodenhaltung auf Einstreu 42 Tage lang gemästet. Das Kationen : Anionen-Verhältnis in den Futtermischungen betrug für die einzelnen Gruppen 250, 350, 250 bzw. 350 mval/kg, der Gehalt an Protein lag bei 17, 17, 23 bzw. 23 %. Die wichtigsten Ergebnisse sind in der folgenden Tabelle dargestellt.

Wichtigste Ergebnisse

Proteingehalt	%	17	17	23	23
(Na + K − Cl)	meq/kg	250	350	250	350
Endgewicht	g	1666	1633	1832	1744
Rohverwertung		1,91	2,02	1,92	2,00
Abdominal- und Innereienfett	%	2,78	2,95	2,51	1,88
Rohfett im Fleisch	%	18,10	18,90	17,50	15,70
Ergebnisse der Kotanalysen:					
Trockenmasse[1]	%	37,10	23,90	49,10	31,70
Rohprotein[2]	%	36,50	28,40	43,30	41,40
Rohasche[2]	%	20,30	23,10	17,90	18,90
Na[2]	%	0,93	1,25	0,56	0,86
K[2]	%	1,28	1,25	1,21	1,29

[1] Ergebnisse in der Frischmasse
[2] Ergebnisse in der Trockenmasse

Die Mastleistung wurde vom Proteingehalt der Ration deutlich beeinflußt. Bezüglich des Anteils des Abdominal- und Innereienfettes am Schlachtkörper sowie des Fettgehalts des Oberschenkelfleisches konnte ein signifikanter Effekt des Proteingehaltes der Ration sowie einer Wechselwirkung zwischen Proteingehalt und Kationen : Anionen-Verhältnis nachgewiesen werden.

Der Gehalt an den angeführten Nährstoffen im Kot wurde sowohl durch den Proteingehalt als auch durch das Kationen : Anionen-Verhältnis beeinflußt, für den Gehalt an Rohprotein und Kalium bestand auch eine signifikante Wechselwirkung zwischen diesen Faktoren.

Aus den vorliegenden Daten kann geschlossen werden, daß die höchste Leistung von den Tieren erreicht wurde, die eine Ration mit 23 % Rohprotein und einem Kationen : Anionen-Verhältnis von 250 mval/kg erhielten.

Schlüsselworte: Broiler, Protein, Kationen : Anionen-Verhältnis, Leistung, Ausscheidungen.

1. Introduction

Protein plays a vital role in the growth and development of chicks. It supplies the individual essential amino acids and a quantity of non essential amino nitrogen to meet the overall needs of the bird. If the protein supply contains each

amino acid in a correct ratio with the others then the quantity of the required protein is minimized, resulting in optimum protein utilization. However as the supply of amino acids in protein deviates from this balance, a great amount of protein is needed and the energy to protein ratio is inevitably reduced (Lewis 1979, Gous and Kleyn 1989).

Like protein, minerals also play an important role in the biochemical and physiological process of the body and hence maintain the normal growth and development of the young birds during the post-embryonic period. The percentage of most minerals in the bodies of young birds increases with mineralization of the skeleton. Accordingly, the mineral requirements during the first two weeks of post-embryonic growth of broilers are especially high (Georgievskii 1982 a). Mineral present as soluble salts in the cell medium, interstitial fluid, blood and lymph, participate directly or indirectly in maintaining the above parameters at a constant level (Georgievskii 1982 b). It has been recognized that the acid-base balance of the bird reflects the ionic balance of the diet. It is known that when the (Na + K − Cl) content of the diet is higher or lower than 25 meq/100 g, the growth of young chicks is depressed (Mongin 1981). This is believed to be due to the fact that when the acid base balance deviates towards either an alkalotic or acidotic situation most of the metabolic pathways cannot work under optimum condition and therefore are more involved in homeostatic regulation than in the growth process. Hence it appears that sodium, potassium and chloride are of paramount importance in controlling the acid base balance and the growth process of young poultry birds not only the total quantity of these minerals is significant in terms of growth, their ratio in the diet is equally important. It is generally recommended that the K/(Na − Cl) ratio should be greater than unitary (Mongin 1981). Since different feed sources contain varying amounts of these ions with varying concentrations of protein and energy, their combination has to be formulated to supply a balance ration.

With these objectives in mind, the present study was undertaken to assess the effect of different levels of dietary protein and electrolyte balance on the performance of broiler chicks.

2. Literature

Nesheim et al. (1964) reported that the toxic effect of Cl could be reversed by increasing the dietary amounts of Na and/or K. Melliere and Forbes (1966) presented evidence indicating the importance of regulating cation-anion balance in the diet of growing chicks. In their study, in which only the levels of Na and K were varied, it was observed that the rate of growth of young chicks was depressed at both very low and high cation : anion ratios. Mongin and Sauveur (1977) indicated that an electrolyte balance of 250 meq (Na + K − Cl)/kg diet was optimum for growth of young chicks. In a more recent study Johnson and Karunajeewa (1985), however reported, the optimum electrolyte balance to be between 250—300 meq/kg diet. Moreover, these authors demonstrated that the electrolyte balance is more important than the total cation-anion balance for the growth of broiler chicks. They concluded that Na, K and Cl are the three key elements in the maintenance of metabolic acid-base balance.

Our knowledge of electrolyte nutrition has been further enhanced by the recent work related to amino acid metabolism and bone formation. The nutrition antagonism of lysine and arginine in diets containing excessive amounts of lysine has been shown in rats (Jones et al. 1966). Excessive dietary lysine interferes with arginine utilization in chickens, in part by increasing renal arginase

activity and consequently increasing arginine degradation. The resulting effect is an increased requirement for arginine (AUSTIC and NESHEIM 1970). High dietary levels of K decrease kidney arginase activity, increase muscle protein synthesis and decrease intestinal bacterial activity in chicks (STUTZ et al. 1972 a). Increasing the dietary levels of mineral cations, especially K and Na, were reported to reduce the severity of the lysine-arginine antagonism in chicks if added in the form of metabolizable organic salts such as acetates or bicarbonates (O'DELL and SAVAGE 1966), while increasing dietary chloride exacerbates (AUSTIC and CALVERT 1981). ADEKUNMISI and ROBBINS (1987 a) reported that increasing the electrolyte balance (Na + K − Cl) in broiler ration 200—350 meq/kg improved gain and feed consumption of chicks fed diets high in protein (28.6 %) but depressed gain and feed consumption of chicks fed diets with low protein content (14.3 %). They further demonstrated that increasing Cl in high Na and K diets also depressed growth in both high and low protein diets. Similar results are reported in other experiments by the same authors (ADEKUNMISI and ROBBINS 1987 b). LEACH (1959) showed that increasing the protein content of the diet resulted in an increase in the potassium requirement of chicks. This response might be due to the role of K in protein biosynthesis (SCHLESSINGER 1964, LUBIN and ENNIS 1964, COHN and LUBIN 1978). This biosynthetic role of potassium was substantiated by the study of REINHART et al. (1968) who indicated that chicks fed a semi-purified diet deficient in K incorporated significantly less leucine into skeletal muscle protein than did chicks which were fed a diet containing adequate levels of potassium. A similar response was found by ALEXIS et al. (1971). In another study of STUTZ et al. (1972 b) increased incorporation of L-lysine into muscle protein was noticed when a high-lysine, low arginine diet was supplemented with K-acetate. Thus it could be concluded that the ameliorating action of the dietary K and the lysine-arginine antagonism in chicks might be due more to the increased lysine incorporation into muscle protein than to the increased lysine catabolism indicated by AUSTIC et al. (1977) and SCOTT and AUSTIC (1978).

3. Material and methods

The experiment was conducted for six weeks at the Fa. Geflügelhof Fehringer to see the effect of different levels of dietary protein and electrolyte balance on the performance of broiler chicks. The experimental room was thoroughly cleaned and disinfected with commercial disinfectant before the arrival of the chicks. The temperature of the experimental room was maintained at 35 °C in the beginning. The birds were reared in floorpens. The area of each pen was 1.18 × 2.50 m. One day old *Vedette* broiler chicks were obtained from the commercial hatchery operated by Fa. Geflügelhof Fehringer. All morbid, underweight, overweight and unthrifty chicks were discarded. 1040 chicks were divided into four experimental groups. Each group had four replicates and each replicate had 65 chicks. The total weight of chicks in each pen was recorded.

Four experimental rations were fed to the birds. The diets consisted of different levels of corn, soybean meal and oil with different electrolyte balance. Table 2 and 3 show the experimental plan and the composition of experimental rations.

The third diet (protein level 2, electrolyte balance 1) can be regarded as a typical commercial broiler ration commonly used in Austria.

Results of crude protein analysis of the diets were 17.5, 17.1, 23.0 and 22.8 % respectively. The birds were fed the alloted rations ad-libitum. Clean and fresh water was provided throughout the experiment. The faeces were collected from eight pens (two pens from each group). The faeces were analyzed for dry matter,

Table 2

Experimental plan

Group/level of Protein	ElB[2]	CP[1] %	ElB[2] meq/kg	Replicates n	Chicks n
1	1	17	250	4	260
1	2	17	350	4	260
2	1	23	250	4	260
2	2	23	350	4	260

[1] Crude protein content of the diet
[2] Electrolyte balance (Na + K − Cl) of the diet

Table 3

Composition of experimental rations

Ingredients		Level of CP / Level of ElB	1 / 1	1 / 2	2 / 1	2 / 2
Maizecorn	%		74.2	73.3	60.0	59.0
Soybeanmeal	%		14.0	14.0	27.0	27.0
Fishmeal	%		4.0	4.0	4.0	4.0
Meat and bonemeal	%		2.0	2.0	2.0	2.0
Rapeseed oil	%		1.8	1.8	3.7	3.7
$NaHCO_3$	%		0.7	1.1	0.4	0.9
$KHCO_3$	%		0.4	0.9	0.0	0.5
Mineral mixture	%		2.9	2.9	2.9	2.9

crude protein, total fat, ash and minerals. The four experimental rations were analyzed for dry matter, protein, total fat, ash, starch, sugar, fiber, carotene, xanthophyll, mineral contens and fatty acids. At the end of the experiment weight gain, feed intake, feed consumption and mortality was recorded. From each pen two male and two female birds were randomly selected (64 birds), given numbered foot rings and weighed so that they later could be used for carcass evaluation and meat analysis. All the birds were slaughtered at the Geflügelhof Fehringer slaughter house, sixteen carcasses per group were evaluated subjectively on color, muscles and plucking. After weighing, the carcasses were dissected into wings, breast and legs (thigh plus shank). The fat from the abdomen and stomach was removed and weighed. Also the weight of the stomach, liver, rest carcass, wings, breast and legs was recorded for each bird. The breast meat- after removing the skin- of 16 birds from each group was grilled and tested for organoleptic characteristics (tenderness, juiciness, taste and range were evaluated by 1—4 points; 1 = good, . . ., 4 = bad) by four persons independent of each other. The meat from the thigh portion was analyzed for dry matter, protein, fat and ash. The abdominal and stomach fat was also analyzed for fatty acids.

The statistical analysis of variance was done by LSMLMW (least squares and maximum likelihood)-computer program (Harvey 1987). Evaluation of subjective carcass quality was analyzed by Kruskal-Wallis' H-test and Bonferoni-Holm-test, for data of organoleptic evaluation of meat quality the Friedman-test was used (Essl 1987).

4. Results and Discussion

The results of the experiment are shown in table 4—9. Least square means, residual standard deviation (s) and probability of analysis of variance (P; P_p = for the factor protein level, P_e = for electrolyte balance, P_{pe} = for interaction between

protein level and electrolyte balance) are given for objective characteristics, means and probability for subjective criteria. P-values below 0.05 are estimated to be significant.

Results of fattening performance are shown in table 4.

Table 4

Fattening performance

Protein Electrolyte		1 1	1 2	2 1	2 2	s	P_p	P_e	P_{pe}
Final weight	g	1666	1633	1832	1744	388.6	0.001	0.074	0.352
Feed consumption	g	3097	3223	3449	3403	1370.5	0.035	0.708	0.408
Feed efficiency		1.91	2.02	1.92	2.00	0.511	0.910	0.042	0.580
Protein efficiency	g/kg	323	345	423	439	111.9	<0.001	0.053	0.692
Energy efficiency	MJ/kg	24.81	26.04	24.98	25.56	6.772	0.781	0.115	0.525
Mortality	%	0.59	1.99	2.36	2.18	13.499	0.376	0.569	0.446

Both final weight and feed consumption were significantly effected by the protein level. The higher protein level led to higher values for final weight and feed consumption whereas feed efficiency was influenced only by level of electrolyte balance. At both protein levels high electrolyte balance resulted in worse feed efficiency. Regarding protein efficiency (g consumed crude protein per kg weight gain) the higher protein content as well as the higher electrolyte balance gave worse results. Energy efficiency and mortality remained unaffected.

There were no interactions between protein level and electrolyte balance in any of the criteria mentioned above.

Therefore it can be said that both optimum electrolyte balance which is 250 meq/kg diet as reported by MONGIN and SAUVEUR (1977) and MONGIN (1981), and high levels of protein are necessary for high performance. JOHNSON and KARUNAJEEWA (1985) recommended a slightly different electrolyte balance of 250—300 meq/kg.

Corresponding with the results presented above MELLIERE and FORBES (1966) found depressed growth of young chicks at high cation: anion ratios. In contradiction to the work of ADEKUNMISI and ROBBINS (1987 a, b) who reported that increased electrolyte balance improved performance of chickens fed diets high in protein but depressed growth of chicks fed low protein diets there were no interactions found between protein level and electrolyte balance in the present study.

Results of slaughtering performance are given in table 5 and 6.

Table 5

Slaughtering performance-physical appearence of carcass

Protein Electrolyte		1 1	1 2	2 1	2 2	P
Color	points	1.44^a	1.47^a	$1.93^{a\,b}$	2.50^b	0.003
Muscle	points	1.75	1.93	1.80	1.68	0.893
Plucking	points	1.50	1.40	1.60	1.62	0.728
Fat	points	2.81^b	2.40^b	$1.87^{a\,b}$	1.31^a	<0.001

Differences in muscle and plucking were found to be non significant. Regarding color and fat there were significant differences between the groups: the high level of both protein and electrolyte balance gave worse results for carcass color but better ones for fat. Differences between all other groups were not significant.

The poor value for carcass color for the group fed the diet with high protein content and high electrolyte balance might be explained by low dry matter and the high nitrogen (expressed as crude protein) content of the faeces of this group (data presented in table 9).

All other criteria of slaughtering performance are shown in table 6.

Table 6

Slaughtering performance — objective criteria

Protein Electrolyte		1 1	1 2	2 1	2 2	s	P_p	P_e	P_{pe}
Carcass weight	g	1446	1432	1491	1458	82.4	0.148	0.333	0.679
Dressing percentage	%	84.62	85.55	85.36	84.33	2.212	0.706	0.938	0.133
Breast	g	214	216	231	224	29.4	0.151	0.750	0.638
Leg	g	368	353	362	361	36.0	0.926	0.424	0.489
Wing	g	143	138	146	149	11.0	0.027	0.737	0.181
Breast plus leg percentage	%	38.32	39.59	41.65	39.83	5.043	0.231	0.852	0.295
Abdominal and stomach fat	g	40	43	38	28	9.1	0.002	0.156	0.027
Fat percentage	%	2.78	2.95	2.51	1.88	0.574	<0.001	0.187	0.021
Liver	g	32	33	31	33	8.8	0.893	0.693	0.879

The most important objective characteristics of slaughtering performance were not influenced by level of protein or electrolyte balance of the diet. An exception was fat (weight and fat percentage of the carcass). Lower protein content of the diet led to higher fat deposition in the carcasses and there was also a significant interaction between protein content and electrolyte balance: in diets with lower protein content higher electrolyte balance led to more fat, for diets with high protein level the contrary to this was observed.

Comparable to this ADEKUNMISI and ROBBINS (1987 a, b) found positive effects of high electrolyte balance in high protein diets but negative effects in low protein diets on broiler performance. The results for carcass fat content presented above are consistent with the characteristics of physical appearance of carcass shown in table 5.

Weight of carcass, breast, leg and wing were significantly effected by sex also. Female birds had lower weights compared to male birds.

Results of chemical analysis of meat and fat are presented in table 7.

Table 7

Chemical analysis of meat and abdominal fat

Protein Electrolyte		1 1	1 2	2 1	2 2	s	P_p	P_e	P_{pe}
Dry matter	%	36.2	36.3	35.5	34.2	1.44	0.002	0.193	0.103
Protein	%	17.2	16.5	17.0	17.5	0.88	0.089	0.702	0.028
Fat	%	18.1	18.9	17.5	15.7	1.93	0.002	0.414	0.028
Ash	%	1.0	0.9	1.0	1.0	0.07	0.164	0.285	0.241
Myristic acid	%	0.6	0.6	1.1	0.6	0.48	0.133	0.136	0.158
Myristoleic acid	%	0.4	0.4	0.4	0.5	0.24	0.673	0.742	0.965
Palmitic acid	%	27.2	26.3	25.0	22.9	2.33	<0.001	0.380	0.402
Palmitoleic acid	%	6.6	6.2	5.4	4.8	1.43	0.003	0.226	0.879
Stearic acid	%	4.5	4.6	4.2	4.2	0.63	0.059	0.911	0.739
Oleic acid	%	45.3	46.9	46.5	44.6	2.60	0.500	0.842	0.026
Linoleic acid	%	13.0	12.7	13.4	17.0	2.26	<0.001	0.016	0.006
Linolenic acid	%	1.8	1.7	2.5	2.9	0.69	<0.001	0.551	0.309

Protein content of the diet significantly effected content of dry matter and fat of the thigh muscle. Regarding protein content of meat P_p was 8.9 %. Higher protein level in the diet resulted in significantly lower dry matter and fat content of the meat whereas there was a tendency towards higher protein percentage.

Regarding protein and fat percentage there was also a significant interaction between protein level and electrolyte balance of the diet: increasing the electrolyte balance led to higher protein and lower fat content of the meat of the birds fed the high protein diets whereas the birds of the low protein groups showed lower protein and higher fat percentage of the thigh muscle with increased electrolyte balance.

This is consistent with the results of the slaughtering performance shown in table 5 and 6 and with the data presented by ADEKUNMISI and ROBBINS (1987 a, b).

As it is shown in table 7 fatty acid pattern of abdominal fat was effected significantly by the protein level. This is due to incorporation of 3.7 % rapeseed oil in the high protein diets whereas in the low protein diets only 1.8 % were incorporated. This resulted in lower levels of saturated and monounsaturated fatty acids and higher levels of linoleic and linolenic acid in the adipose tissue of the birds fed the high protein diets.

The meat was judged for the organoleptic characteristics tenderness, juiciness, taste and range. The results are indicated in table 8.

Table 8

Organoleptic characteristics of broiler meat

Protein Electrolyte		1 1	1 2	2 1	2 2	P
Tenderness	points	1.5	1.5	1.7	1.5	0.201
Juiciness	points	1.7	1.8	2.0	1.8	0.245
Taste	points	1.8	1.9	2.1	2.0	0.453
Range		2.8	3.0	3.2	3.2	0.630

This table represents non significant data for all these characteristics.

The analysis of birds' faeces was also conducted in this experiment. The most important results are shown in table 9 (dry matter content is given on basis of fresh faeces; protein, fat, ash and mineral content on dry matter-basis).

Table 9

Chemical analysis of faeces

Protein Electrolyte		1 1	1 2	2 1	2 2	s	P_p	P_e	P_{pe}
Dry matter	%	37.1	23.9	49.1	31.7	2.67	<0.001	<0.001	0.068
Crude protein	%	36.5	28.4	43.3	41.4	1.20	<0.001	0.004	0.021
Crude fat	%	6.6	6.1	6.0	6.3	0.39	0.453	0.715	0.291
Ash	%	20.3	23.1	17.9	18.9	0.62	0.002	0.012	0.122
Ca	%	3.67	4.16	3.36	2.96	0.151	0.002	0.711	0.014
P	%	1.89	1.78	1.68	1.51	0.074	0.010	0.059	0.569
Na	%	0.93	1.25	0.56	0.86	0.057	<0.001	0.002	0.816
K	%	1.28	1.25	1.21	1.29	0.017	0.218	0.084	0.012

Increasing the protein content of the diet resulted on the one hand in increasing excretion of dry matter and nitrogen (in table 9 expressed as crude protein)

with the faeces and on the other hand in significantly decreasing faeces' content of ash and — corresponding with this — calcium, phosphorus and sodium.

The increase of dry matter percentage of the faeces can be explained by the typically higher crude protein excretion because fat percentage remained unchanged and ash content even decreased. The latter together with the significantly lower content of the most important minerals in the faeces could be due to the higher performance of the birds fed the high protein diets; thus causing a higher demand for the above mentioned minerals.

The results of LEACH (1959) who showed that higher protein levels led to a higher potassium requirement were not confirmed by the present study where no significant effect of protein level on potassium excretion was found.

Increased electrolyte balance (corresponding with higher sodium percentage) of the diet caused a significantly higher ash and especially sodium excretion whereas dry matter and protein content of the faeces decreased; probability in phosphorus and potassium were only slightly higher than 5 %. For crude protein, calcium and potassium content of the faeces significant interactions were observed: high electrolyte balance together with low protein content of the diet resulted in typical reduction of nitrogen (crude protein) percentage of the faeces, whereas reduction was not so distinct for high protein diets.

Following the data presented by ADEKUNMISI and ROBBINS (1987 a, b) the interaction in calcium could be due to the significantly higher performance of the birds fed the high protein diets, thus causing a higher demand for calcium whereas higher electrolyte balance in the low protein diets caused higher calcium excretion.

There is no explanation for the interaction in potassium but differences between groups are not so high compared to the other nutrients.

It can be concluded from the data presented here that level of dietary protein and electrolyte balance — as described by (Na + K − Cl) — clearly effects broiler performance and chemical composition of carcass and birds' faeces. Optimum performance was achieved with 23 % crude protein and electrolyte balance of 250 meq/kg.

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