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FEEDING STUDIES FOR AMINO ACID AND ENERGY SUPPLY OF BROILER CHICKENS FED DIETS WITH LOW CRUDE PROTEIN CONTENT

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The candidate has fulfilled all the requirements of the Doctoral Regulations of the Hungarian University of Agricultural and Life Sciences and has taken into account the comments and suggestions made in the workshop discussion of the thesis when revising it, therefore the thesis may be submitted for the defence procedure.

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Approval by the Head of the Doctoral School

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1. Background and objectives

Chicken meat is one of the most valuable sources of protein for humanity. This is due to the good biological utilization of the protein and its favourable amino acid composition. Due to its low energy, sodium and fat content, as well as its favourable polyunsaturated fatty acid composition, it is easy to include it even in special diets. Globally, poultry meat production is the largest among meat species with 139 million tons (2021-23), exceeding pork (122 million tons) and other species (OECD/FAO, 2024). Broiler meat production dominated this, accounting for approximately 103 million tons in 2024, and further growth is expected.

Animal husbandry is a source of pollutants that damage water, soil and air quality, and is one of the most significant emitters of ammonia emissions. Several technologies have been developed to reduce nitrogen and ammonia emissions from the poultry sector. Among the feeding methods, the most effective solution is to feed low protein (LP) diets. Reducing the crude protein content of the diet by 1% can result in a reduction of nitrogen and ammonia excreted in the excreta by approximately 10% (Santonja et al., 2017). Lower nitrogen intake can also reduce water intake in broilers, which leads to improved litter quality (dryer litter), lower risk of foot pad dermatitis, skin irritation and blistering of the breast muscle (Swiatkiewicz et al., 2017). Reduced protein feeding results in less undigested protein entering the hindgut, which can result in a reduction in the incidence of dysbiosis and necrotic enteritis, and in the amount of antibiotics used (Wu, 2014). Low protein diets generally contain less imported soybean and a higher proportion of crystalline amino acid supplements, which can lead to significant economic and ecological benefits: the use of local, European protein sources can be prioritized, deforestation, the transportation distance of raw materials and thus the carbon footprint of feed production can be reduced (Gasparri et al., 2013). Depending on the prices of soy products, crystalline amino acids and local protein sources, feed prices can decrease, and production can become more economical.

Nowadays, the study of various probiotic feed supplements plays a major role in research related to the improvement of the health of the digestive tract, its microbiota, and the reduction of antibiotic use. The study of LP diets and probiotics in broiler chickens has been investigated separately by several research groups, but there are far fewer examples of joint studies in the literature. Another less studied topic is the adjustment of the energy (AMEn) level of LP feeds, since the AMEn content maintained at the same level while reducing the protein level (isocaloric LP feeds) usually creates an energy surplus and increases the deposition of abdominal fat in chickens (Swennen et

al., 2006). From the point of view of amino acid supply, it is important to keep the standardized ileal digestibility (SID) value of as many essential amino acids as possible at the "level" corresponding to the required (control) value when reducing the crude protein content of LP feeds by increasing the proportion of synthetic amino acid supplements. In recent years, the question of the role of non-essential amino acids has also come to the fore, with glycine being the first limiting non-essential amino acid to be investigated (Siegert and Rodehutscord, 2019). Research into the glycine supply of broiler chickens is complicated by the fact that it depends on numerous factors (e.g., threonine, serine, methionine, cysteine, betaine, choline availability). In the future, the demand for feed ingredients that can serve as natural sources of glycine when feeding LP diets may increase.

Based on the above, the objectives of my thesis can be summarised as follows:

1. In my first experiment, the combined effect of *Bacillus amyloliquefaciens* CECT5940 strain and diets with reduced crude protein content in broiler chickens free from Eimeria infection were investigated. The conventional crude protein content of the control diet in the grower (-1.5%) and finisher phases (-2%) was reduced, and conventional and low protein-level diets were supplemented with the probiotic, i.e. four treatments were used in total. In addition to the different protein levels, identical SID values for a total of six essential amino acids (lysine, methionine, threonine, arginine, valine, isoleucine) were considered based on the amino acid requirements of the animals. During the experiment, I intended to compare the effect of protein level, probiotic effect, and possible protein-probiotic interactions regarding production results, slaughter value, and the morphological state of the intestinal tract.

2. In the second model experiment, I aimed to examine the effect of reduced crude protein (LP) feeding (-1.5%), with different AMEn/crude protein ratios of the diet. In addition to an isocaloric diet with a control (C) crude protein content (LP1), the relative decrease in AMEn in LP2 and LP3 diets was smaller (1.5 and 3.0%, respectively) than the relative decrease in the crude protein content, which was a new approach in broiler feeding. Accordingly, I investigated the effects of protein-reduced diets with different AMEn/crude protein ratios on the production parameters of broilers, carcass composition, breast meat quality, nitrogen retention and excreta N-composition, and apparent ileal digestibility of starch and amino acids.

3. In the third model experiment, my goal was to compile practically applied "traditional" and low protein (-2%) diets, with which I could examine the importance of glycine as a primarily limiting non-essential amino acid. In addition to the control and a soybean-based low protein diet (LPS) compiled

along the principles applied in previous experiments, a glycine-rich swine meat meal (LPM) was used to maintain the glycine equivalent value (Gly_{equi}) in one of the LP diets. The use of swine meat meal is justified by the EU ban on the use of crystalline glycine as a feed additive. Threonine is the precursor of glycine and accordingly an elevated crystalline threonine supplement was used in one of the low protein diets (LPST). In the experiment, I intended to investigate the effects of feed treatments on broiler production parameters, carcass composition, breast meat quality, nitrogen retention and the proportion of N-forms in excreta, and the apparent ileal digestibility of starch and amino acids.

2. Materials and methods

2.1. Effects of probiotic-supplemented diets with reduced crude protein content on the production parameters and intestinal morphological status of broiler chickens (Experiment 1)

2.1.1. Experimental animals and their housing

The experiment was conducted at the Georgikon Campus of the Hungarian University of Agricultural and Life Sciences, Institute of Physiology and Animal Nutrition. The experiment started with a total of 576 Ross 308 genotype day-old male broilers, which were obtained from the Gallus Ltd. hatchery (Gallus Kft., Devecser, Levente farm 1.). The animals were immunized in the hatchery against infectious bronchitis (Cevac Bron), Newcastle disease (Cevac Vitapest) and infectious bursitis (Cevac Ttransmune) with vaccines from Ceva (Ceva Santé Animale, 33500 Libourne, France). The day-old chicks were placed in a closed room automatically controlled by a computer system, providing uniform, optimal environmental conditions for all experimental pens. The birds were randomly distributed in experimental pens with a deep litter system, where 24 animals were placed in a pen (14 birds/m^2). Chopped wheat straw was used as bedding. Chickens were provided with ad libitum access to feed and drinking water throughout the fattening period. The lighting, heating and ventilation program was set according to the specifications of the breeding company Aviagen (Aviagen, Newbridge, United Kingdom, 2019). To prevent coccidiosis, chickens were treated with a live attenuated coccidiosis vaccine (Evant ®, Hipra) at 6 days of age. The room temperature was set to 32 C° on day 0 at the level of day-old animals. The room temperature was then gradually reduced until it reached 20 C° on day 27, which was continuously ensured until the end of the experiment. The relative humidity of the house during fattening ranged between 60-70%. In the first week of the experiment, the light intensity was 30 lux, and then from the 2nd week until the end of the experiment, the light intensity was set to 10 lux. In the first week, the lighting program consisted of a 23-hour light and 1-hour dark period, which was replaced by a 20-hour light and 4-hour dark period from the 2nd week until the end of the experiment. The animal experiment was approved by the Institutional Ethics Committee (Animal Protection Committee, Georgikon Campus, Hungarian University of Agricultural and Life Sciences) under the license number MÁB-4/2022.

2.1.2 Experimental dietary treatments

During the experiment, we used a three-phase feeding: starter (0-10 days; kibble), grower (11-24 days; granulated) and finisher (25-39 days; granulated) phases. In the starter phase, a control (C) and a diet supplemented with a

probiotic (Ecobiol 500® 0.5 g/kg bw; *Bacillus amyloliquefaciens* CECT 5940 (BA), min. 2 x 109 CFU/g; Evonik Nutrition & Care GmbH, Germany) were fed (C+BA), in 12 replicates (pens) per treatment. The experimental diet of group C was a diet that met the suggested requirements of the Ross 308 hybrid (Aviagen, 2019). During the grower and finishing phases, four experimental diets were fed, each with 6 replicates: control (C; 6 pens of the starter treatment), probiotic-supplemented diet (C+BA; 6 pens of the starter C+BA group), low protein diet (LP; 6 pens of the starter C treatment), low protein diet supplemented with probiotic (LP+BA; 6 pens of the starter C+BA treatment). In the LP groups, the crude protein content was 1.5% lower in the grower phase and 2.0% lower in the finisher phase compared to the control (C). The experimental diets were prepared at the Georgikon Campus of MATE. In the LP and LP+BA groups, the reduction in crude protein content was achieved by reducing the proportion of extracted soybean meal. Crystalline amino acid supplementation was used for six essential amino acids (lysine, methionine, threonine, valine, isoleucine, arginine). When calculating the diets of the different treatments, we aimed to ensure that the standardized ileal digestibility (SID) values were the same for these amino acids. When determining the SID value and the ratios of essential amino acids to lysine, we took into account the recommendations of the AminoChick2.0® software from Evonik (Evonik, 2014). None of the diets fed in the experiment contained coccidiostats. Feed raw materials and experimental diets were stored in a dry and cool place (<20°C).

2.1.3 Measurements and sampling procedures

The body weight of the chickens was measured individually at the age of one day and at the end of each feeding phase (day 10, 24 and 39), after which the body weight gain was determined. Also, at the end of the phases, the feed consumption per pen was measured, after which the average feed intake and feed conversion for the given pen were calculated. During the statistical analysis of the production parameters, we worked with pen averages (6 repetitions per treatment; n=6). When the experimental animals were 29 days old, intestinal morphology and intestinal content were examined with the help of the employees of Vet-Produkt Kft. Based on the "intestinal health monitoring program" provided by Evonik, the digestive system was examined on 3-3 birds of average body weght per cage. During the slaughter of the selected animals, the individuals were bled under carbon dioxide stunning by cutting the jugular vein. The individual parameters were determined by an experienced specialist from Vetprodukt Kft. using sensory examination. During the evaluation, the presence (1 point) or absence (0 points) of the following characteristics was recorded per animal: intestinal gas, dysbacteriosis, necrotic enteritis, increased intestinal mucus production,

Peyer's patches of intensive red colour, thin intestinal wall. The coccidiosis examination was performed according to the so-called "Lesion scoring" evaluation method developed by Johnson and Reid (1970). Based on this method, intestinal lesions caused by Eimeria species were assessed in four sections of the intestine (duodenum, jejunum, ileum, caecum). The severity of the lesions was scored with a value of 0-4, with 0 points given when there were no lesions and 4 points when very severe lesions were visible. The total score given per bird was divided by the number of intestinal sections, and the resulting ratio was evaluated.

The carcass weight and composition of the animals was determined on the 39th day of fattening. After carbon dioxide stunning, 48 animals were killed per treatment. The carcass weight (the ratio of the ready-to-eat body weight to the live weight), the relative breast fillet ratio to the live weight, the relative thigh ratio and the relative abdominal fat ratio were determined. The ready-to-eat body weight was the weight measured after the animals were skinned, the digestive tract, the head and the feet were removed.

2.1.4. Analytical methods and calculations

The crude protein (MSZ EN ISO 5983-2:2005), crude fat (MSZ EN ISO 6492), crude fiber (MSZ EN ISO 6865: 2001), total phosphorus (MSZ EN ISO 6491: 2001) and calcium (MSZ EN ISO 6869: 2001) contents were determined from the experimental diet samples.

2.1.5. Statistical analysis

Data preparation for statistical analysis was performed using Microsoft Office Excel 2010, and then evaluated using IBM SPSS (version 22, SPSS, Inc., Chicago, IL, USA) statistical analysis package. During the evaluation of production and slaughter parameters, each pen represented the experimental unit. The screening of outliers was followed by checking the homogeneity of variances (Levene test). The results of the starting phase were evaluated with a t-test, while the effects of protein reduction and probiotic supplementation were evaluated with a two-way analysis of variance (ANOVA). In the latter case, if the effect of any factor proved to be significant based on the F-test, the Tukey test was used to detect differences between treatments. Except for coccidiosis scoring (Mann-Whitney test), the incidence rates of intestinal health changes were evaluated with a Chi^2 test. Differences between groups were considered significant at $P<0.05$.

2.2 The effect of diets with different energy-protein ratios and reduced crude protein content on the production and carcass traits, meat quality and nitrogen metabolism of broiler chickens (Experiment 2)

2.2.1 Experimental animals and their housing

The location of the experiment, the genotype, sex, number of experimental animals, the incubation treatments, the housing conditions and the husbandry technology used during the experiment were completely identical to those described in Experiment 1. The animal experiment was approved by the Institutional Ethics Committee (Animal Protection Committee, Georgikon Campus, Hungarian University of Agricultural and Life Sciences) under the license number MÁB-1/2021.

2.2.2. Experimental dietary treatments

Four dietary treatments consisting of six replicates with 24 broilers in each were established, and experimental diets were fed in the starter (day 0–10), grower (day 11–24), and finisher (day 25–41) phases. A control diet (C) was formulated in line with the breeder's recommendations for Ross 308 (Aviagen, Newbridge, United Kingdom). Low protein (LP) diets LP1, LP2, and LP3 contained 1.5% less crude protein (CP) than diet C in each dietary phase. This CP reduction in LP diets meant 6.5, 7.0, and 8.0% relative reductions compared to the control diets in the starter, grower, and finisher phases, respectively. The LP1 diet was isocaloric with the control, but the diets LP2 and LP3 had 1.5% and 3.0% lower AMEn content. The reduction in CP content in LP diets was achieved by reducing the ratio of extracted soybean meal, while the reduced dietary AMEn content was ensured by reducing the proportion of sunflower oil. Diets were formulated based on standardized ileal digestible (SID) amino acids in accordance with the ideal protein concept. LP diets were supplemented with six feed-grade crystalline essential amino acids (Lys, Met, Val, Thr, Arg, and Ile) to meet the calculated concentrations of SID AA in the C diets. All diets contained phytase and xylanase enzymes, but no amino acid-releasing impact of these enzymes was considered in the diet formulations.

2.2.3 Measurements and sampling procedures

Individual body weight (BW) and feed intake (FI) of broilers per pen were recorded at the end of each dietary phase. Body weight gain (BWG) and feed conversion ratio (FCR) were calculated on a pen basis at the end of each phase as well as for the whole trial peri-od. Mortality and the weight of dead broilers were registered daily during the whole trial.

At day 35, the individual BW of broilers was measured, and two broilers with aver-age body weight from each pen (with individual BW within the range of mean BW per pen ± 2%; 12 broilers per treatment) were selected and transferred to balance cages, where broilers consumed the same finisher diets, but supplemented with 0.5% titanium dioxide as an indigestible internal marker. After four days adaptation period, representative excreta samples were collected from each bird daily for two consecutive days (days 40 and 41). The samples of 12 broilers per treatment were pooled, mixed thoroughly, frozen, and stored at −20 °C until analysis. Before the analyses, excreta was homogenized properly, then the dry matter content, total-N, ammonium-N (NH4+-N), and uric acid-N contents determined.

At the end of the experiment, two broilers per pen (12 broilers per treatment) representing the average body weight of the pen were selected and slaughtered by cervical dislocation. After evisceration, carcass composition (% of carcass weight, % of breast meat, % of thigh weight, % of abdominal fat) and breast meat quality were determined. The pH of the breast muscle, *Pectoralis major* (*P. major*), was measured immediately after slaughtering (pH_{0h}) and after 24 h storage at 4 °C (pH_u) with a portable pH meter (Testo 205; Testo Ltd., Budapest, 1139, Hungary) by inserting a glass electrode directly into the thickest of the breast muscle, always 2 cm from the caudal end of *P. major*. The water-holding capacity of meat was estimated by measuring drip loss of the raw meat: the *P. major* muscle was weighed immediately after slaughter and placed in a plastic bag, hung from a hook, and stored at 4 °C for 24 h. After hanging, the sample was wiped with absorbent paper and weight again. The difference in weight corresponded to the drip loss and was expressed as the percentage of the initial muscle weight.

2.2.4. Analytical methods and calculations

The analytical measurements were performed in the laboratory of the Department of Animal Nutrition and Animal Nutrition Physiology of MATE ÉTI, in the Festetics Imre Bioinnovation Center of the Georgikon Campus. The collected fresh excreta and intestinal contents samples were oven-dried at 60 °C for 72 hours before further processing. The dry matter content (MSZ ISO 6496:2001), crude protein (MSZ ISO 5983-1:2005), starch (Regulation 152/2009/EC Annex III. L), phosphorus (MSZ ISO 6491:2001) and calcium (MSZ EN ISO 6869:2001) content and amino acid composition (MSZ EN ISO 13903:2005) were determined from the feed samples.

The dry matter content of excreta samples was determined after drying in a drying oven (100 C° for 24 hours, until constant weight) (MSZ ISO 6496:2001). The total-N content of the excreta was determined from the dried sample using the Kjeldahl method (MSZ ISO 5983-1:2005) using a Foss-

Kjeltec 8400 analyzer (Nils Foss Allé 1, DK-3400 Hilleroed, Denmark). NH_4^+-N was determined according to the method of Peters (2003), while uric acid-N was determined according to the method of Marquardt (1983). All N parameters were calculated on a dry matter basis. The urine-N content was the sum of ammonium-N and uric acid-N (Scott et al., 1982). The TiO_2 content of the diets, excreta and gut contents was determined using UV spectroscopy (Ferguson et al., 1998). The starch and amino acid content of the gut contents (AAA 400; Ingos, Czech Republic) was measured according to the methods described above for the feed analysis. The protein (MSZ ISO 937:2002) and fat (MSZ ISO 1443:2002) contents of the breast muscle were determined. Based on the measurement results, N retention was calculated using the following equation (Bregendahl et al. 2002): Apparent nitrogen retention = 1 − [([TiO_2] diet/[TiO_2] excreta) × ([nitrogen] excreta/[nitrogen] diet)]. The apparent ileal digestibility of starch and amino acids was calculated according to the above retention equation, with the following modifications: instead of N, the starch/amino acid concentration was included in the equation, and the concentrations measured in the intestinal contents were used instead of excreta.

2.2.5. Statistical analysis

Data of individual broilers were statistically evaluated except in the case of body weight gain, feed intake, and feed conversion ratio, which parameters were evaluated based on pens as experimental units. The averages of examined parameters were analysed as a completely randomized design by one-way analysis of variance (ANOVA) with dietary treatments as main effects after testing of normal distribution (Kolmogorov–Smirnov test) of data and homogeneity of variances (Levene-test). When the F-test revealed a significant treatment effect, the significant differences between groups were tested by the Tukey HSD test. Regression analysis was used to evaluate the relationship between the calculated dietary starch:CP ratio and the mean FCR of broilers per pen in the starter phase. All statistical analyses were carried out by the software package SPSS 22.0 for Windows (IBM Corp., Armonk, NY, USA). Statistical significance has been declared at $P<0.05$.

2.3. Effect of different threonine and glycine supply in broiler chickens fed on diets with reduced crude protein content (Experiment 3)

2.3.1. Experimental animals and their housing

A floor pen trial was carried out at the experimental farm of the Institute of Physiology and Nutrition, Georgikon Campus, Hungarian University of Agriculture and Life Sciences (Keszthely, Hungary). A total of 576 one-day-old male broiler chickens (Ross 308) were purchased from a local hatchery

(Gallus Ltd., Devecser, Hungary) and divided randomly into 24 floor pens at a stocking rate of 24 birds per pen (14 bird/m2). Animals were vaccinated against infectious bronchitis (CEVAC BRON), Newcastle disease (CEVAC VITAPEST), and infectious bursal disease (CEVAC TRANSMUNE) in the hatchery using vaccines produced by Ceva (Ceva Santé Animale, France). Chopped wheat straw was used as litter material. The animals were provided ad libitum water and feed during the entire duration of the experiment. The climatic conditions and light program, based on the breeder's guidelines, were computer-controlled and identical for all pens. The room temperature was set to 34 °C on day 0 and reduced gradually to 24 °C at 18 days of age. The light intensity was 30 lux in the first week, and 10 lux thereafter with a constant day length of 23 h from day 0 to day 7 and 20 h light and 4 h dark period thereafter. The study protocol was approved by the Institutional Ethics Committee (Animal Welfare Committee, Hungarian University of Agriculture and Life Sciences) under the license number MÁB-3/2022).

2.3.2. Experimental dietary treatments

Three dietary phases were used during the 35-day-long experiment: starter (from 0 to10 day), grower (from 11 to 24 day), and finisher (from 25 to 35 day). All birds were fed the same starter phase diet and 4 dietary treatments consisting of 6 replicates with 24 birds in each were established and experimental diets were fed in the grower and finisher phases in pelleted form. The design of the experiment is described in Table 1. Diets of the control C treatment were formulated in line with the breeder's recommendations for Ross 308 (Aviagen, Newbridge, United Kingdom) and adequate in levels of CP and SID essential AA. Low protein (LP) diets, LPS, LPST and LPM contained 2.0% less crude protein than diet C with control CP level in each dietary phase. Dietary treatments were different in SID Thr level and SID Thr-to-Lys ratio as well as SID (Gly+Ser)-to-Lys ratio and the Gly_{equi}. The experimental LP diets were isocaloric with diet C. The increased Gly_{equi} in the LPM diet was achieved by the partial replacement of soybean meal with swine meat meal rich in Gly. Diets were formulated based on standardized ileal digestible (SID) amino acids in accordance with the ideal protein concept. LP diets were supplemented with six feed-grade crystalline essential amino acids (Lys, Met, Val, Thr, Arg, and Ile) to meet the calculated concentrations of SID amino acids in the C diets except for the SID Thr level of LPST diet. All diets contained phytase and xylanase enzymes, but no amino acid-releasing impact of these enzymes was considered in feed formulations.

2.3.3 Measurements and sampling procedures

The measurements and sampling performed during the experiment were the same as those described in Chapter 2.2.3., with the difference that the

retention-digestion experiment in the metabolic cages was performed by a five-day adaptation period, after which representative excreta sample collection was performed on days 41 and 42 of life.

The analytical measurement methods and calculations performed during the experiment were the same as those described in Chapter 2.2.4. The statistical analysis was performed in the same way as in Chapter 2.2.5.

3. Results and discussion

3.1 Effects of probiotic-supplemented diets with reduced crude protein content on the production parameters and intestinal morphological status of broiler chickens (Experiment 1)

The most important production parameters of the experimental animals are listed in Table 1. The different crude protein content of the diets as a treatment effect was evaluated from the rearing stage of fattening. In the case of production results, a significant effect of the crude protein content of the feeds was observed, namely that the animals of the protein-reduced LP groups achieved significantly (P<0.001) higher body weight on day 39 and more favourable feed conversion ratio in the grower-finisher period compared to the animals of the control (C) group.

Table 1. Effect of experimental treatments on body weight, feed intake and feed conversion ratio of broiler chickens (mean ± SD)

Treatments		Body weight (g)	Feed intake (g/bird)	Feed conversion ratio (kg/kg)
Crude protein content	Pro-biotic	day 39	grower and finisher phase	grower and finisher phase
Control (C)	BA-	2090.2 ± 67.6	3506.7 ± 71	2.07 ± 0.1
	BA+	2119.1 ± 108.6	3523.7 ± 126	2.07 ± 0.1
Low protein (LP)	BA-	2360.6 ± 124.4	3499.4 ± 132	1.82 ± 0.1
	BA+	2209.5 ± 113.7	3423.4 ± 132	1.90 ±0.1
Crude protein effect				
Control (C)		2104.7 ± 88.1 [a]	3515.2 ± 98.5	2.08 ±0.1[b]
Low protein (LP)		2285.1±119.1[b]	3461.4 ± 132	1.86 ±0.1[a]
Probiotic effect				
BA-		2225.4 ± 96.0	3503.0 ±101.5	1.96 ± 0.1
BA+		2164.3 ± 111.2	3473.6 ±129.0	1.99 ± 0.1
Level of significance (P value)				
Crude protein effect (1)		<0.001	NS	<0.001
Probiotic effect (2)		NS	NS	NS
Interaction (1x2)		NS	NS	NS

BA -/+ = without probiotic/with probiotic; [a, b] means with different superscripts of the same column are significantly different (P<0.05 vagy P<0,001)); NS = non-significant (P>0.05); n=6

Based on the carcass traits analysis performed at the end of the experiment, the treatments did not affect the carcass weight, the relative breast fillet or thigh ratio (P>0.05). However, when examining the relative abdominal fat ratio, it was found that compared to the control, feeding the protein-reduced diets significantly increased the incorporation of abdominal fat (Control: 0.37% vs. LP: 0.55; P<0.05). In the LP group, the proportion of abdominal fat decreased due to the probiotic (LP BA+) compared to the group without probiotic (LP BA-) (P<0.05). However, this probiotic effect was not detected in the control group. The results of the intestinal morphology and intestinal content analysis are presented in Table 2.

Table 2. Results of intestinal morphology and intestinal content examination

Tretaments		**Coccidiosis score[1]** (n=6) (mean ± SEM)	**Incidence rate of lesions found in the intestine (%; n=18)**	
Crude protein content	Pro-biotic		**Gas production**	**Red Peyer'spatches**
Control (C)	BA-	0.416 ± 0.057	55,6	33,3
	BA+	0.333 ± 0.061	27,8	16,7
Low protein (LP)	BA-	0.277 ± 0.135	50,0	55,6
	BA+	0.333 ± 0.086	22,2	16,7
Crude protein effect				
Control (C)		0.375 ± 0.042	41.7	25.0
Low protein (LP)		0.305 ± 0.077	36.1	36.1
Probiotic effect				
BA-		0.374 ± 0.073	52.8[b]	44.4[b]
BA+		0.333 ± 0.050	25.0[a]	16.7[a]
Level of significance (P value)				
Crude protein effect (1)		NS	NS	NS
Probiotic effect (2)		NS	<0.05	<0.05
Interaction (1x2)		NS	NS	NS

BA -/+ = without probiotic/with probiotic; [a, b] means with different superscripts of the same column are significantly different (P<0.05 vagy P<0,001)); NS = non-significant (P>0.05); n=6

Coccidiosis test scores were not affected by the feeding treatments. In the case of animals not consuming probiotics, intense gas production in the intestine was present in 52.8%, which was reduced by almost half, to a 25.0% incidence rate, by the use of probiotics. Another striking and proven beneficial effect of the probiotic was that the Peyer's patches of the intestinal wall were less pronounced and showed less bright red colour (16.7%), which was 44.4% in the case of broilers without probiotics.

3.2. The effect of diets with different energy-protein ratios and reduced crude protein content on the production and carcass traits, meat quality and nitrogen metabolism of broiler chickens (Experiment 2)

The most important fattening performance parameters measured during the experiment are listed in Table 3. The experimental diets had a significant effect on the body weight of the broilers at the end of the experiment (day 41; $P<0.05$) but did not affect the feed intake and feed conversion ratio for the entire experiment. The combined reduction of the crude protein and energy content of the diet (LP2 and LP3) negatively affected the body weight of the chickens, which was significantly lower compared to the control ($P<0.05$).

Table 3. Effects of dietary treatments on production parameters (mean ± SEM)

Treatment	Body weight (g)	Feed intake (g)	Feed conversion ratio (kg/kg)
C	2928.1 ± 23.5 ^{c}	4674.7 ± 57.0	1.66 ± 0.02
LP1	2855.7 ± 26.2 ^{bc}	4691.1 ± 75.0	1.70 ± 0.04
LP2	2770.1 ± 28.8 ^{ab}	4496.0 ± 60.9	1.69 ± 0.01
LP3	2744.0 ± 28.4 ^{a}	4467.4 ± 62.4	1.69 ± 0.03
Significance (P)	<0.001	NS	NS

C—control diet; LP1—reduced crude protein levels (−1.5%) and isocaloric AMEn content compared to the control diet; LP2—reduced crude protein (−1.5%) and AMEn levels (−1.5%) compared to the control diet; LP3—reduced crude protein (−1.5%) and AMEn levels (−3%) compared to the control diet; a,b means with different superscripts of the same column are significantly different ($P<0.05$); NS—nonsignificant ($P>0.05$); n = 12 broilers per treatment

Feeding the experimental diets did not affect the carcass weight, relative thigh weight and abdominal fat percentage (Table 4). However, the breast meat percentage was significantly affected by the feeding treatments ($P<0.05$). The breast meat percentage of birds fed the isocaloric, reduced crude protein diet (LP1) was significantly higher than in the control group ($P<0.05$).

The highest N retention was measured in the experimental animals belonging to the LP2 group, which was significantly higher than the values of broilers in the C and LP3 groups ($P<0.05$; Figure 1). In addition, significantly higher N retention was also found in the LP1 group than in the control. There was no significant difference between the N retention values of broilers receiving the C and LP3 treatments ($P>0.05$).

Table 4. Carcass weight and composition 1 (mean ± SEM, n=12)

Treatment	Carcass weight (%)	Breast meat yield (%)	Thigh weight (%)	Abdominal fat (%)
C	65.41 ± 0.31	21.41 ± 0.31 [a]	19.63 ± 0.22	0.49 ± 0.08
LP1	66.85 ± 0.41	23.20 ± 0.49 [b]	19.41 ± 0.38	0.70 ± 0.10
LP2	66.08 ± 0.26	22.65 ± 0.26 [ab]	19.22 ± 0.23	0.49 ± 0.07
LP3	65.94 ± 0.46	22.78 ± 0.54 [ab]	19.27 ± 0.35	0.62 ± 0.06
Significance (P)	NS	0.026	NS	NS

C—control diet; LP1—reduced crude protein levels (−1.5%) and isocaloric AMEn content compared to the control diet; LP2—reduced crude protein (−1.5%) and AMEn levels (−1.5%) compared to the control diet; LP3—reduced crude protein (−1.5%) and AMEn levels (−3%) compared to the control diet; 1 values expressed as a percentage of live BW; a,b means with different superscripts of the same column are significantly different (P < 0.05); NS—nonsignificant (P > 0.05), n = 12 broilers per treatment

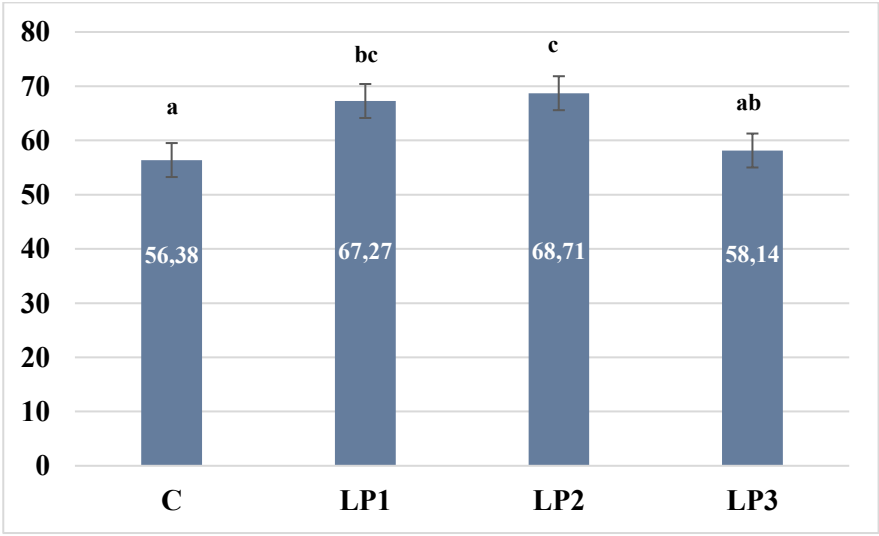

Figure 1. *Effect of dietary treatments on N retention of broilers (%; mean ± SEM; n = 12 broilers per treatment).*

C—control diet; LP1—reduced crude protein levels (−1.5%) and isocaloric AMEn content compared to the control diet; LP2–reduced crude protein (−1.5%) and AMEn levels (−1.5%) compared to the control diet; LP3—reduced crude protein (−1.5%) and AMEn levels (−3%) compared to the control diet; [a,b,c] means with different superscripts are significantly different (P< 0.05).

Reducing the crude protein content of the diets in the LP1 group significantly reduced the concentrations of fecal N, uric acid N and total N in excreta compared to treatment C (Table 5; P<0.05). Reducing the AMEn content of

the diets (LP1-LP3) increased the concentrations of the measured nitrogen forms in the excreta.

Table 5. The concentration of N-forms in broiler excreta (mean ± SEM, n=12)

Treatment	Fecal-N	NH_4^+-N	Uric acid-N	Urinary-N[1]	Total-N
	mg/g Dry Matter				
C	32.75 ± 2.33 [b]	4.58 ± 0.26	17.65 ± 1.13 [b]	22.23 ± 1.34	54.98 ± 3.62 [b]
LP1	21.96 ± 1.26 [a]	5.20 ± 0.41	13.07 ± 0.76 [a]	18.27 ± 1.12	40.24 ± 2.32 [a]
LP2	25.94 ± 1.84 [ab]	4.76 ± 0.40	15.03 ± 1.09 [ab]	19.79 ± 1.44	45.73 ± 3.15 [ab]
LP3	33.42 ± 2.45 [b]	4.92 ± 0.55	18.25 ± 1.49 [b]	23.16 ± 2.01	56.58 ± 4.38 [b]
Significance (P)	<0.001	NS	0.009	NS	0.004

[1] The sum of NH_4^+-N and uric acid-N was considered as urinary-N content; C—control diet; LP1—reduced crude protein levels (−1.5%) and isocaloric AMEn content compared to the control diet; LP2—reduced crude protein (−1.5%) and AMEn levels (−1.5%) compared to the control diet; LP3—reduced crude protein (−1.5%) and AMEn levels (−3%) compared to the control diet; a,b means with different superscripts of the same column are significantly different (P<0.05); NS—nonsignificant (P>0.05), n = 12 broilers per treatment

The ileal digestibility of starch was significantly higher in the protein and energy-reduced LP2 and LP3 groups than in the C and LP1 treatments (Table 6). The ileal digestibility of amino acids was also significantly higher in the LP groups than in the C group.

Table 6. Effect of experimental treatments on apparent ileal digestibility of starch and amino acids (mean ± SEM, n=12)

Treatment	Starch	Amino acid (average)
C	92.71 ± 0.32 [a]	88.25 ± 0.38 [a]
LP1	93.18 ± 0.36 [a]	91.50 ± 0.21 [bc]
LP2	94.83 ± 0.28 [b]	91.21 ± 0.18 [b]
LP3	95.18 ± 0.21 [b]	92.23 ± 0.11 [c]
Significance (P-value)	<0.001	<0.001

C—control diet; LP1—reduced crude protein levels (−1.5%) and isocaloric AMEn content compared to the control diet; LP2—reduced crude protein (−1.5%) and AMEn levels (−1.5%) compared to the control diet; LP3—reduced crude protein (−1.5%) and AMEn levels (−3%) compared to the control diet; a,b means with different superscripts of the same column are significantly different (P<0.05); (P>0.05), n = 12 broilers per treatment

3.3. Effect of different threonine and glycine supply in broiler chickens fed on diets with reduced crude protein content (Experiment 3)

Considering the entire rearing period, only broiler chickens receiving LPST treatment achieved significantly higher body weight at slaughter (day 35) compared to the control (Table 7, $P<0.05$).

Table 7. Production parameters of experimental animals (mean ± SEM; n=6)

Treatment	Body weight (g; day 35)	Feed intake (g)	Feed conversion ratio (kg/kg)
C	2479.9 ± 25.6 [a]	3351.0 ± 16.8	1.40 ± 0.01[b]
LPS	2617.1 ± 46.2 [ab]	3489.9 ± 59.7	1.36 ± 0.01[ab]
LPST	2633.3 ± 37.9 [b]	3419.1 ± 9.6	1.33 ± 0.01[a]
LPM	2579.2 ± 30.4 [ab]	3447.7 ± 50.5	1.36 ± 0.01[ab]
P-value	0.029	NS[1]	0.026

C - control diet; LPS – soybean meal-based diet with reduced crude protein levels (-2%); LPST– soybean meal based diet with reduced crude protein levels (-2%) and higher crystalline L-Threonine supplementation; LPM – diet with reduced crude protein levels (-2%) in which soybean meal partially replaced with swine meat meal as protein source; [1]NS – non significant ($P>0.05$); [a,b] Means with different superscripts in the same column are significantly different ($P<0.05$);

During the entire rearing period, the feed conversion ratio value was the best in the LPST group, which was significantly more favourable than in the control group, but did not differ significantly from the other two protein-reduced treatments. In contrast to the body weight and feed conversion ratio data, no significant difference was found in the feed intake of broilers between the treatments in any phase of the experiment. In the LPS and LPST groups, the carcass weight did not differ compared to the control group (Table 8). However, in the meat meal treatment, it was significantly lower than in the C and LPST groups. Furthermore, feeding the LPM experimental diet significantly increased (relative) abdominal fat incorporation compared to the C group ($P<0.05$).

The effect of the feeding treatments on N retention is shown in Figure 2. Experimental animals of the LPM group achieved significantly higher N retention than animals of group C ($P<0.05$).

Table 8. Carcass weight and composition[1] (%, mean ± SEM; n=12)

Treat-ment	Carcass weight	Breast meat yield	Thigh weight	Abdominal fat
C	65.67 ± 0.45 [b]	22.37 ± 0.35	19.21 ± 0.29	0.68 ± 0.09 [a]
LPS	65.18 ± 0.42 [ab]	21.20 ± 0.50	19.00 ± 0.20	0.98 ± 0.09 [ab]
LPST	66.25 ± 0.25 [b]	22.25 ± 0.34	19.15 ± 0.20	0.87 ± 0.08 [ab]
LPM	64.06 ± 0.32 [a]	20.92 ± 0.45	18.92 ± 0.19	1.04 ± 0.09 [b]
P-érték	<0.001	NS[2]	NS	0.032

[1] Values expressed as percentage of live BW; C - control diet; LPS – soybean meal-based diet with reduced crude protein levels (-2%); LPST– soybean meal based diet with reduced crude protein levels (-2%) and higher crystalline L-Threonine supplementation; LPM – diet with reduced crude protein levels (-2%) in which soybean meal partially replaced with swine meat meal as protein source; [2]NS – non significant (P>0.05); [a,b] Means with different superscripts in the same column are significantly different (P<0.05);

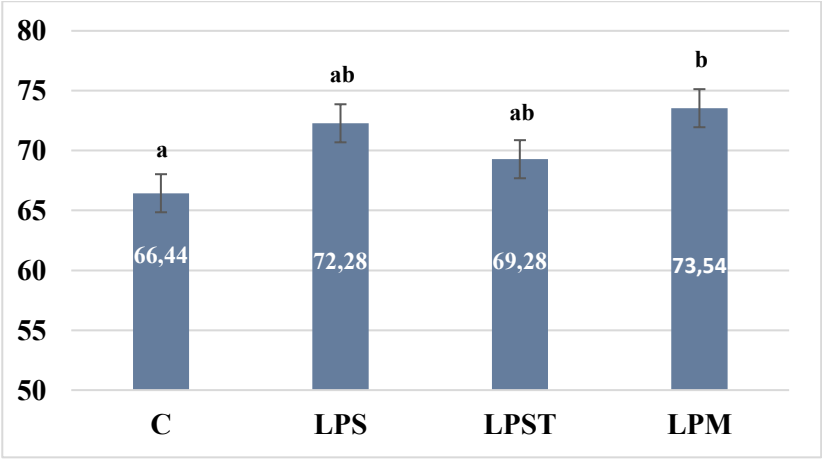

Figure 2. *Effect of dietary treatments on the efficiency of dietary N retention (mean + SEM; n=12)*

C - control diet; LPS – soybean meal-based diet with reduced crude protein levels (-2%); LPST– soybean meal based diet with reduced crude protein levels (-2%) and higher crystalline L-Threonine supplementation; LPM – diet with reduced crude protein levels (-2%) in which soybean meal partially replaced with swine meat meal as protein source; [a,b] Means with different superscripts in the same column are significantly different (P<0.05)

The experimental treatments did not significantly affect the concentrations of fecal-N, uric acid-N, NH_4^+-N, urinary-N and total-N in the excreta of broiler chickens. No significant differences were found in ileal starch digestibility between groups. However, the average ileal digestibility of amino acids in the LPM group was significantly higher than in the other groups (Table 9).

Table 9. Apparent ileal digestibility of starch and amino acids (%, mean ± SEM; n=12)

Treatment	Starch	Amino acids (average)
C	89.61 ± 0.37	86.76 ± 0.34 [a]
LPS	88.94 ± 0.44	88.12 ± 0.47 [ab]
LPST	89.38 ± 0.49	88.25 ± 0.43 [ab]
LPM	89.49 ± 0.35	89.05 ± 0.40 [b]
P-value	NS[1]	<0.05

C - control diet; LPS – soybean meal-based diet with reduced crude protein levels (-2%); LPST– soybean meal based diet with reduced crude protein levels (-2%) and higher crystalline L-Threonine supplementation; LPM – diet with reduced crude protein levels (-2%) in which soybean meal partially replaced with swine meat meal as protein source; [1] NS – non significant (P>0.05); [a,b] Means with different superscripts in the same column are significantly different (P<0.05).

4. Conclusions and recommendations

In all three experiments conducted during my doctoral research, the protein reduction in LP diets was 1.5 or 2.0 % compared to the control diets. Our results confirm the already known relationship that a crude protein reduction of approx. 2% compared to the needs of broiler hybrids can be achieved without deterioration of production results, and the principles applied in the formulation of our recipes can be safely recommended for practice. The amino acid needs of the experimental animals were met based on the "ideal protein" principle, on a digestible amino acid basis. When reducing the crude protein content of isocaloric diets, I used six types of crystalline amino acid supplements (L-lysine, DL-methionine, L-valine, L-threonine, L-arginine, L-isoleucine), and thus managed to achieve that the SID concentration of the most important essential amino acids (lysine, methionine, methionine+cysteine, threonine, valine and isoleucine) remained at the same level as the control diets, corresponding to the required value. In contrast, in the control diets, the SID arginine level was higher than the required values even without synthetic arginine supplementation. In the LP diets, however, I ensured SID arginine concentrations that met the requirements with the crystalline arginine supplements, which resulted in only small (0.5-1.2 g/kg) concentration differences between the control and protein-reduced diets in favour of the control treatments. By feeding broilers low protein diets and amino acid composition detailed above, the production results do not deteriorate compared to the control diets, and in fact, a significant improvement in production parameters can be achieved compared to the control diet with normal protein content.

Based on the results of experiment 1, it can be said that the probiotic (*Bacillus amyloliquefaciens* CECT 5940) supplementation applied to both normal and reduced crude protein diets probably does not improve fattening performance parameters in practice, but when fed together with reduced crude protein diets, it may reduce the accumulation of abdominal fat. The positive effect observed in the experiment may be due to the reduced triglyceride synthesis and lower acetyl-CoA carboxylase enzyme activity in the liver as a result of the probiotic treatment. Although we did not experience symptoms indicative of coccidiosis, in my opinion, the lower efficacy of the coccidiosis vaccine used instead of coccidiostats in the experiment may have played a role in the fact that during the subjective observation-based digestive tract examination, we detected unusually high intestinal gas content, specifically bright red Peyer's patches. The probiotic used was able to improve the condition of the intestinal contents, reduce the intense gas formation observed in the intestines and support the immune system (reducing the incidence of bright red Peyer's

patches), regardless of the crude protein concentration of the diets. It would be worthwhile to examine probiotic treatment with methods suitable for objective, quantitative comparison, and in the case of diets containing coccidiostats in the future.

In my 2nd experiment investigating the different AMEn/crude protein ratios of LP diets, the AMEn/crude protein ratio of LP diets was higher than that of the control (C) diet, the relative decrease in AMEn of LP2-3 diets was smaller than the 6.5, 7.0 and 8.0% relative decrease in crude protein in the starter, grower and finisher phases. The energy reductions (LP2-3) negatively affected the growth performance compared to the control, as well as the more favourable N retention achieved with the isoenergetic LP1 diet than the control and the fecal, uric acid and total-N concentrations of the excreta. Due to the mentioned negative effects, the energy reductions used in the experiment cannot be recommended for practice, and in order to establish the optimal energy content of LP diets, I suggest examining the AMEn reductions of less than 1.5% that I used. One of the main goals of the experiment was to achieve results in reducing the increased amount of abdominal fat often experienced in the case of isocaloric LP diets. Since the relative weight of abdominal fat in my experiment (0.4-0.7%) was unusually low and, unlike many previous experiments, the isoenergetic LP1 treatment did not significantly increase the proportion of abdominal fat compared to the control, I was unable to formulate any recommendations in this regard. The difference in the AMEn content of the diet between the LP1-3 diets was achieved by reducing the crude fat content of the feed, while the starch concentration, thus the starch/crude protein and starch/lipid ratios, increased. The higher starch/crude protein ratio of LP diets may worsen feed conversion ratios, as was demonstrated in the starter phase of my experiment and in the studies of other researchers. It would be worthwhile to further investigate the topic to achieve energy reduction without changing the crude fat content of the diets, primarily by reducing the starch content, and to determine the significance of starch and crude fat concentrations when adjusting the energy content of LP diets.

In the 3rd experiment, I examined different glycine supply of broilers, by varying the Gly_{equi} and SID threonine concentrations of the diets. The results suggest that a 2% reduction in crude protein content applied in the grower and finisher phases (LPS treatment; from 21% to 19% in grower, from 19% to 17% in finisher) with amino acid supply following the ideal protein principle) does not result in a reduction in Gly supply to such an extent that it negatively affects the performance of broilers compared to the control treatment. The LPST treatment examined the effect of increased Thr supply using crystalline Thr supplementation. In LPST diets, an increase of 0.10% in the SID Thr

concentration and 9.0% in the SID Thr/Lys ratio in both the grower and finisher phases with the same Gly_{equi} value as the LPS treatment can significantly improve the body weight at slaughter age and feed conversion ratio for the entire fattening period compared to the control, while the carcass traits, breast meat quality, N-retention and excretion are similar. Based on the results, the applied changes in the Thr concentration can also be recommended for practice. With the LPM diet using swine meat meal as a natural glycine source, while reducing the crude protein content by 2%, maintaining a Gly_{equi} concentration similar to the control, a comparable fattening performance, a more favourable feed conversion ratio in the finisher phase, and an improved efficiency of N-retention can be achieved. However, the treatment can result in a lower carcass weight and an increased abdominal fat ratio, therefore further development of the composition of the LP diet containing swine meat meal is necessary.

Summarizing and combining the results of all three experiments, I would recommend for practice, in the case of the Ross 308 broiler hybrid, LP diets with 2% lower crude protein content than the requirement throughout the fattening period, in line with the ideal protein principle, and the SID concentration of the most important essential amino acids (lysine, methionine, methionine+cysteine, arginine, valine, isoleucine) corresponds to the requirement. The SID threonine content should exceed the requirement by approximately 0.1% (0.84% in the grower, 0.74% in the finisher), and the diet should also contain the probiotic preparation I tested (*Bacillus amyloliquefaciens* CECT 5940) at a concentration of 500 mg/kg. In my opinion, the recommended feed can be expected to provide the same fattening performance as that achieved with a conventional diet, or even exceeding it, similar carcass traits, abdominal fat ratio and breast meat quality, higher N retention and a more favourable composition of excreta (lower total and/or urine N content) in terms of N emission.

5. New scientific results

1. The use of the probiotic (*Bacillus amyloliquefaciens* CECT 5940 preparation; 500 mg/kg) in a broiler chicken (Ross 308) diet did not affect the proportion of abdominal fat in animals consuming the control crude protein-containing diet, but in the case of the reduced crude protein diet (rearing -1.5%, finishing -2.0%), it significantly ($P<0.05$) decreased the degree of abdominal fat accumulation.

2. Compared to the control diet, feeding diets with reduced crude protein (-1.5%) and energy content (AMEn value relative -1.5 and -3.0%) significantly ($P<0.05$) reduced the body weight and weight gain of broiler chickens, but did not affect the carcass composition, the protein and fat content of breast meat, or the concentration of various N-containing compounds in the excreta.

3. Compared to the control diet, feeding diets with reduced crude protein (-1.5%) and energy content (AMEn value relative -1.5 and 3%) significantly ($P<0.05$) improved the apparent ileal digestibility of starch and all essential amino acids.

4. In the reduced crude protein content diet (-2% in the rearing and finishing stages), a SID threonine:lysine ratio 9% higher than the technological recommendations significantly ($P<0.05$) improved the body weight of broilers at slaughter age, the weight gain for the entire fattening period and feed conversion ratio of broiler chickens, as well as the apparent ileal digestibility of lysine, threonine, arginine, alanine and valine.

5. In the reduced crude protein content diet (-2% in the rearing and finishing stages), the Gly_{equi} value of the diet maintained at the same level using swine meat meal as a rich source of glycine (15.77 g/kg in the rearing, 13.55 g/kg in the finishing stage) significantly ($P<0.05$) improved N retention. However, its use increases the starch/crude protein ratio of the diet, which negatively affects carcass yield and increases the proportion of abdominal fat.

6. Publications related to the topic of the dissertation

I. Publications in peer-reviewed journals in foreign language

Strifler, P.; Horváth, B.; Such, N.; Farkas, V.;Wágner, L.; Dublecz, K.; Pál, L. (2023) Effects of feeding low protein diets with different energy-to-protein ratios on performance, carcass characteristics, and nitrogen excretion of broilers. Animals 13: 1476. https://doi.org/10.3390/ani13091476

Strifler P, Horváth B, Such N, Dublecz K and Pál L (2024) Effects of different dietary threonine and glycine supplies in broilers fed low-protein diets. Front. Vet. Sci. 11:1373348. doi: 10.3389/fvets.2024.1373348

II. Publications in peer-reviewed journals in Hungarian

Strifler, P., Horváth, B., Bencze-Nagy, J., Such, N., Csitári, G., Dublecz, K., Pál, L. (2023) Csökkentett nyersfehérjeszintű, probiotikummal kiegészített takarmányok hatásai brojlercsirkék termelési eredményeire és bélegészségügyi jellemzőire. Állattenyésztés és Takarmányozás, 72 (1). pp. 29-47. ISSN 0230-1814

III. Publications in full length in peer-reviewed conference proceedings

Strifler, P., Such, N., Horváth, B., Rawash, M., A., Wágner, L., Dublecz, K., Pál, L. (2021) Csökkentett nyersfehérje tartalmú takarmányok és egy probiotikus készítmény hatása brojlercsirkék termelési paramétereire. In: XXVII. Ifjúsági Tudományos Fórum, Keszthely, Magyarország, Magyar Agrár- és Élettudományi Egyetem, Georgikon Campus pp. 9-14.

Strifler, P., Horváth, B., Such, N., Zsarnóczay, S., Dublecz, K., Pál, L. (2022) Eltérő nyersfehérje- és energiaszintű takarmányok hatása brojler kakasok termelési eredményeire, nitrogénretenciójára és az ürülék nitrogénformáira. In: XXVIII. Ifjúsági Tudományos Fórum, Keszthely, Magyarország, Magyar Agrár- és Élettudományi Egyetem, Georgikon Campus pp. 139-144.

IV. Publications in abstract form in conference proceedings

Strifler, P., Horváth, B., Such, N., Bencze-Nagy, J., Wágner, L., Dublecz, K., Pál, L. (2021) Eltérő nyersfehérje- és energiaszintű takarmányok hatása brojlercsirkék termelési paramétereire, vágóértékére és húsminőségére In: LXII. Georgikon Napok konferenciakötet, A klímaváltozás kihívásai a következő évtizedekben, Keszthely, Magyarország Szent István Egyetem, Georgikon Campus, p.23, 1 p.

Strifler, P., Horváth, B., Such, N. A., Farkas, V., Csitári, G., Wágner, L., Dublecz, K., Pál, L. (2021) Csökkentett nyersfehérje szintű takarmányozás hatása brojlercsirkék vakbél mikrobiótájára. In: Szalka, Éva (szerk.) „Innováció és digitalizáció": XXXVIII. Óvári Tudományos Nap, Absztraktkötet, Mosonmagyaróvár, Magyarország, Széchenyi István Egyetem Mezőgazdaság- és Élelmiszertudományi Kar, pp. 40-40., 1 p.

Strifler, P., Horváth, B., Such, N. A., Kisjuhász, G., Dublecz, K., Pál, L. (2022) Effects of low protein diets and probiotic supplementation on gut health parameters of broiler chickens. In: Vladimir, Brajković; Vlatka, Čubrić Čurik; Ino, Čurik; Ivana,

Držaić; Mario, Shihabi (szerk.) ASD 2022 - Book of Abstracts, 30th International Symposium Animal Science Days 2022, Zágráb, Horvátország, University of Zagreb, Faculty of Agriculture, 115 p. pp. 74-74., 1 p.

Strifler, P., Such, N. A., Farkas, V., Horváth, B., Dublecz, K.,Pál, L. (2023) Effect of different energy levels of low protein diets on the nitrogen retention and excretion of broiler chickens, In: 23rd European Symposium on Poultry Nutrition - Book of Abstracts, Rimini, Olaszország: World's Poultry Science Association (WPSA), 446 p. p. 237 Paper: PS2-0, 1 p.

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