

APPLICATION OF THE IDEAL PROTEIN CONCEPT IN BROILER NUTRITION

PRIMJENA KONCEPCIJE IDEALNE BJELANČEVINE U HRANIDBI BROJLERA

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Summary

The responses observed in the five experiments suggest that the genetic potential of current broiler strains is very high and probably not a limiting factor under practical feeding conditions. Increasing the whole ideal amino acid profile substantially improved performance - not only weight gain and feed conversion, but also breast meat yield. On the other hand, nitrogen utilisation dropped dramatically with increasing IP levels. It could also be shown that male and female birds responded the same way to increased amino acid supply in the starter phase. Data obtained by the last experiment clearly demonstrated that the whole range of essential amino acids has to be considered to get the full response. However, the first limiting amino acids contribute a major portion to the potential effect.

INTRODUCTION

Genetic potential of current broiler breeds has been improved considerably during recent years. Apart from weight gain and feed conversion ratio breeder companies focus more and more on breast meat yield. It is well known that these performance criteria - especially breast meat yield - respond sensitively to suboptimum amino acid supply. However, increasing performance potential likely leads to changes in nutrient and thus amino acid requirement.

On the other hand the development of the "Ideal Protein" concept has been an important progress on the animal nutrition side. This concept suggests that the ratios between the essential amino acids and lysine (as reference amino acid)

are almost not influenced while the quantitative amino acid requirement is affected by many factors. The aim of the present experiments was to examine the response of modern broiler types to increasing levels of dietary protein which is balanced according to the "Ideal Protein" concept.

THE IDEA OF THE "IDEAL PROTEIN" CONCEPT

The basic idea of the Ideal Protein (IP) concept is that birds need amino acids in a certain balance to ensure optimum performance. Amino acids in relative excess compared to the first limiting amino acid will be oxidised and nitrogen will be excreted. Therefore, adjusting the dietary amino acid supply according to the "Ideal Protein" concept helps to optimize protein utilization.

In practical application of this concept, it is possible to establish low protein diets allowing for the same animal performance as compared to unbalanced high protein diets. An other possibility of this concept is the calculation and formulation of the bird's requirement for essential amino acids, as the ratios between these amino acids remain fairly stable.

Therefore, only the responses of one single reference amino acid -usually lysine- to changing production conditions have to be evaluated while the remaining amino acids are then to be adjusted simply by calculation. The concept only considers essential amino acids. However, there is still a scientific discussion about the adequate ratio between essential and non-essential amino acids especially in low protein diets.

LYSINE IS THE REFERENCE AMINO ACID

In swine nutrition lysine has been established as reference amino acid mainly because lysine is the first limiting amino acid in swine diets. Although this is not the case in common broiler diets - here methionine and cystine (Met+Cys) are first limiting in most cases - lysine (Lys) is taken as the reference amino acid as well supported by the following arguments:

Lys is almost exclusively utilised for body protein accretion and thus requirement is only affected very little by other metabolic functions (maintenance requirement) or feathering as this is the case for Met+Cys.

There are no metabolic interactions between Lys and other amino acids. In contrast, Met can be converted to Cys by the bird but the opposite way is not possible.

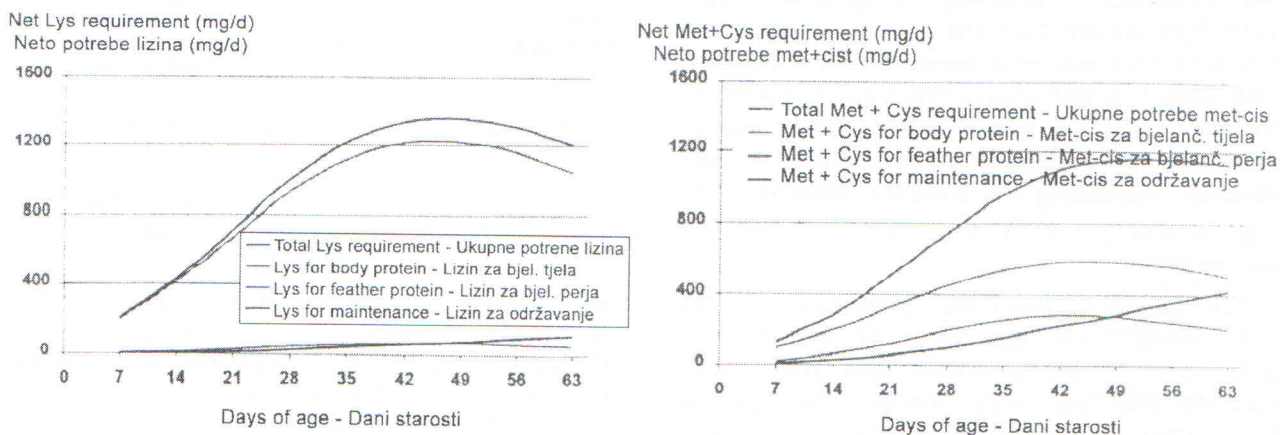
There are various ways to determine an "Ideal Amino Acid Profile"

Diferent scientific approaches to obtain ideal amino acid profiles have been described, according to the literature survey, the factorial approach, the dose response studies and the deletion method.

The factorial approach is based on the concept that the requirement for an amino acid can be divided into three parts: requirement for body protein accretion, for feather growth and for maintenance. In Figure 1, the daily net requirement of Lys (left) and Met+Cys (right) for broilers over a period of eight weeks is shown. The overall requirement for Lys and Met+Cys is not that different but the contributions of protein accretion, feather growth, and maintenance to total

Figure 1. Daily net Lys (left) and Met+Cys (right) requirement for broilers from 7 to 63 days of age, expressed as a total and differentiated between requirements for body protein deposition, feather growth, and maintenance

Slika 1. Dnevne neto potrebe lizina (lijevo) i met + cistina (desno) za brojlerne od 7 do 63 dana starosti izražene kao ukupne i odvojene potrebe za pohranjivanje bjelančevina, rast perja i održavanje



requirement differ markedly between both amino acids. Lys is almost exclusively used for protein accretion, whereas relatively high proportions of Met+Cys are required for feather growth and maintenance. Since the latter is a function of body weight, it increases with age. This underlines the advantage of Lys vs. Met+Cys as the reference amino acid.

Examples for ideal amino acid profiles obtained by the factorial approach are the Illinois Ideal Chicken Protein published by Baker (1994) and GfE (1999) (Table 1).

It should be noted that Baker (1994) related the profile to digestible amino acids, whereas GfE (1999) gave ratios on a total amino acid basis. Ideal amino acid ratios should be based on digestible rather than total amino acids because digestibility can interfere with the ideal ratios. This becomes important when raw materials with different amino acid digestibilities are used. The amino acid profile arriving at the respective tissues is crucial, and it can be different from the dietary amino acid composition due to losses during digestion.

DOSE RESPONSE STUDIES

As outlined above, the weakness of the factorial approach is the assumption of linear dose-response relationships regarding the utilisation of absorbed amino acids. This downside can be overcome by conducting simultaneous or multiple dose-response studies. Thus, the growth and body composition responses of birds can be used to derive amino acid requirements including utilisation of absorbed amino acids. Moreover, experimental conditions like feed composition, feed ingredients or environmental aspects can be kept as uniform as possible.

In a project of Mack et al. (1999) an exponential model was used in dose response studies and was an optimum true fecal digestible Lys level of 1.15%. This figure reflects the level required to minimise feed conversion in two Lys experiments, the profile established in this European project is also given in table 1. Recently, an ideal protein for starting broiler chicken has been published which was determined by the deletion method (Gruber, 1999, partly published by Gruber et al., 2000), a method

originally established in swine research. The deletion method is based on the concept that the reduction of a non-limiting amino acid has no effect on nitrogen retention. The change in nitrogen retention (as % of N-intake) due to a reduced proportion of each amino acid is used to determine a dietary amino acid profile in which all the amino acids tested were equally limiting - an ideal protein.

In summary, it can be stated that - although there are different methods to determine an ideal protein - available results are fairly similar. Apparent differences could be attributed to the method applied for ideal protein determination but also to interactions between amino acid requirements and other animal related and/or environmental factors. The most important factors are age, climate, management as well as genetic factors like sex or strain. Applying the ideal protein concept - regardless of small variations - has been shown to be effective.

How do current broiler strains respond to increased levels of dietary protein being balanced according to an ideal amino acid profile?

A series of broiler experiments was conducted in cooperation with Provimi B.V. to investigate the effects of increasing levels of dietary protein balanced according to the Ideal Protein Concept (IP).

The crucial part of all experiments was the formulation of the experimental diets because the ratios between all essential amino acids had to be in agreement with the Ideal Protein Concept (IP). Moreover, the amino acid profiles had to be identical in all experimental diets at least within the individual trial. Therefore, the dilution technique was applied to match these targets.

Diets were formulated to meet energy and nutrient recommendations of the Dutch CVB (Table 2, CVB, 1998) except for amino acids. Depending on the individual experiment, digestible lysine and all remaining essential amino acids were increased from 94% up to 147% of the recommended levels. In order to get graded IP levels, aliquots of a big batch of the respective high IP diet were blended with a dilution mix. The dilution mix did not contain any amino acid or protein but identical mineral, vitamin and energy contents as the high IP diet.

Table 1. Selected "Ideal Protein" profiles (Lys = 100%) for broilers taken from different references
Tablica 1. Odabrani profili: "idealne bjelancevine" (Lys = 100%) za brojlere uzetih iz raznih izvora

Phase - Razdoblje	Starter - Početna					Starter/Grower Početna/lu rastu	Grower - Završna		
	NRC (1994) ^a	GfE (1999) ^b	Baker (1994) ^c	Baker et al. (2002)	Gruber (1999)		NRC (1994) ^a	GfE (1999) ^b	Baker (1994) ^c
Source - Izvor	Literature survey Pregled literature	Factorial approach Faktorski pristup	Factorial approach Faktorski pristup	Dose response study Proučavanje odgovora na dozu	Deletion method Metoda precrtaivanja	Literature survey Pregled literature	Literature survey Pregled literature	Factorial approach Faktorski pristup	Dose response study Proučavanje odgovora na dozu
Method - Metoda									
Based on ... amino acids - Temeljeno na aminokiselinama	Total Ukupno	Total Ukupno	True digestible Zaista probavljivo	True digestible Zaista probavljivo	True digestible Zaista probavljivo	Apparent digestible Naoko probavljivo	Total Ukupno	True digestible Zaista probavljivo	True digestible Zaista probavljivo
Lys (%) of diet	1.10 ^e	1.09 ^{e,f}	1.12 ^g	1.03 ^g	not stated	1.05/1.02 ^e	1.00 ^e	0.89 ^g	1.15 ^g
Amino acid ratios to Lys - Odnos amino kiselina prema lizinu									
Met	46	36	36	-	37	38	38	38	-
Met+Cys	82	71	72	-	70	73	72	75	75
Thr	73	67	67	56	66	65	74	70	63
Trp	18	16	16	17	14	16	18	17	19
Arg	114	108	105	-	108	105	110	105	112
Ile	73	69	67	61	63	66	73	67	71
Leu	109	112	109	-	108	-	109	109	-
Val	82	96	77	78	81	80	82	77	81
Phe+Tyr	122	118	105	-	121	-	122	105	-
His	32	32	35	-	38	-	32	32	-

a Ratios calculated, not explicitly given in the recommendations – Izračunati omjeri, nisu izričito dati u preporukama

b German Society for Nutrition – Njemačko društvo za hranidbu

c Also known as "Illinois Ideal Chicken Protein" – Također poznat kao "ilinoiska idealna bjelancevina za piliće"

d Also known as CVB (Dutch Centraal Veevoederbureau) recommendations - Također poznat kao CVB preporuke (Nizozemska)

e Mixed sexes – Miješani spolovi

f Recalculated assuming dry matter content of the diet: 88% - Ponovno izračunata pretpostavljena suha tvar obroka 88%

g For male birds – za muške ptice

Table 2. Dietary energy and nutrient levels (g/kg) for starting, growing, and finishing broilers as recommended by CVB (1998)**Tablica 2. Energetske i hranidbene razine obroka (g/kg) za početne, u rastu i završne brojlere prema preporuci CVB (1998).**

Phase - Faza	Starter day 1 to 14 Početna dan 1 do 14	Grower day 15 to 28 U rastu dan 15 do 28	Finisher day 29 to 42 Završna dan 29 do 42
AME* (MJ/kg)	11.9	12.6	12.6
AME (kcal/kg)	2850	3010	3010
Apparent fecal digestible lysine* Naoko probavljiv fekalni lizin	10.5	10.2	9.9
Available phosphorus*** Dostupan fosfor	3.9	2.9	2.7
Calcium*** - Kalcij	8.8	6.6	6.1

* AME for broilers, approximately 7-9% lower than conventional ME figures – AME za brojlere oko 7-9% niži od uobičajenih iznosa ME

** Ratios of digestible amino acids – Omjeri probavljivih amino kiselina: Lys:Met+Cys:Thr:Trp:Arg:Ile:Val = 100:73:65:16:105:66:80 (according to Schutte (1996) in experiments 1,2, (5, partly) and 100:75:63:19:112:71:81 (according to Mack et al. (1999) in experiments 3 and 4).

*** Phases recommended for the phosphorus and calcium figures are 1 to 10, 11 to 30, and 31 to 40 days for the starter, grower, and finisher phase, respectively – Preporučena razdoblja za iznose fosfora i kalcija su 1 do 10, 11 do 30 i 31 do 40 dana za početnu, u rastu i završnu fazu.

Due to this technique not only the ratios between the essential amino acids but also the ratios between the non-essential amino acids to lysine were kept identical. Feed analyses always confirmed proper feed mixing. The experimental diets were mainly based on corn and soybean meal. Nevertheless, due to the high number of restrictions and constraints in linear programming, small fractions of other ingredients such as wheat, wheat gluten, corn gluten, and fish meal were included. The dilution mix mainly consisted of corn starch.

First Experiment

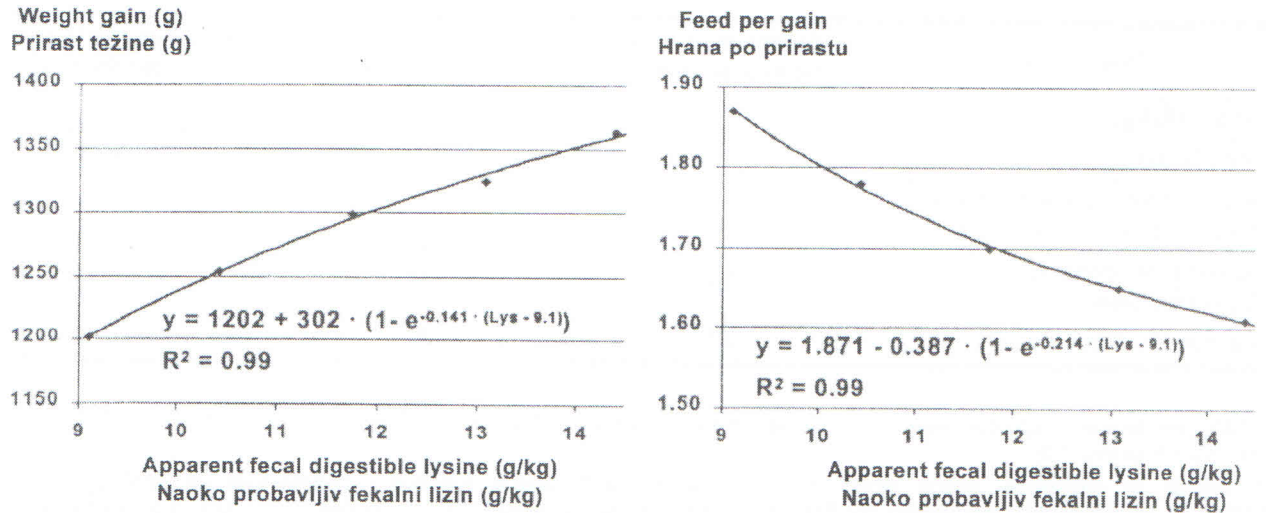
The first experiment was performed with 600 male Ross 208 broilers. After a period of 13 days where the birds received a commercial starter diet, broilers were assigned to five experimental treatments, with six replications a 20 birds each. Five experimental diets were formulated containing graded levels of balanced protein. Thus the ratios between apparent faecal digestible Met+Cys, Thr, Trp, Arg, Val, and Ile and Lys (100%) were at least

75%, 63%, 16%, 105%, 80%, and 66% in all experimental diets. In addition the ratio between non-essential and essential amino acids was also maintained the same in all diets. The level of balanced protein was increased from 17.4% to 26.8% corresponding to 0.91% to 1.44% apparent faecal digestible Lysine. These levels represented 93% and 147%, respectively, of the recommendation according to CVB (1998). Experimental diets were fed from day 14 to 34 and weight gain and feed conversion were determined for this period.

The results are shown in Figure 2. Weight gain improved by 162 g almost linearly from 1201 g to 1363 g and 1.87 to 1.61 with increasing IP levels. Feed conversion improved tremendously by 0.26 kg/kg from 1.87 in birds fed the diet containing 0.91% apparent faecal digestible lysine to 1.61 in birds which received the diets containing 1.44% app. faec. dig. lysine. Prediction of the performance according to breeders recommendation would be 1410 g for weight gain and 1.70 for feed conversion for the same period of time. However, the response curves indicate that further improvements might be possible with even higher IP levels.

Figure 2. Responses of male Ross 208 broilers 14 to 34 days of age to graded levels of Ideal Protein expressed as apparent fecal digestible lysine

Slika 2. Odgovori 14 do 34 dana starih muških brojlera Ross 208 na klasificirane razine idealne bjelančevine izraženih kao probavljiv fekalni lizin

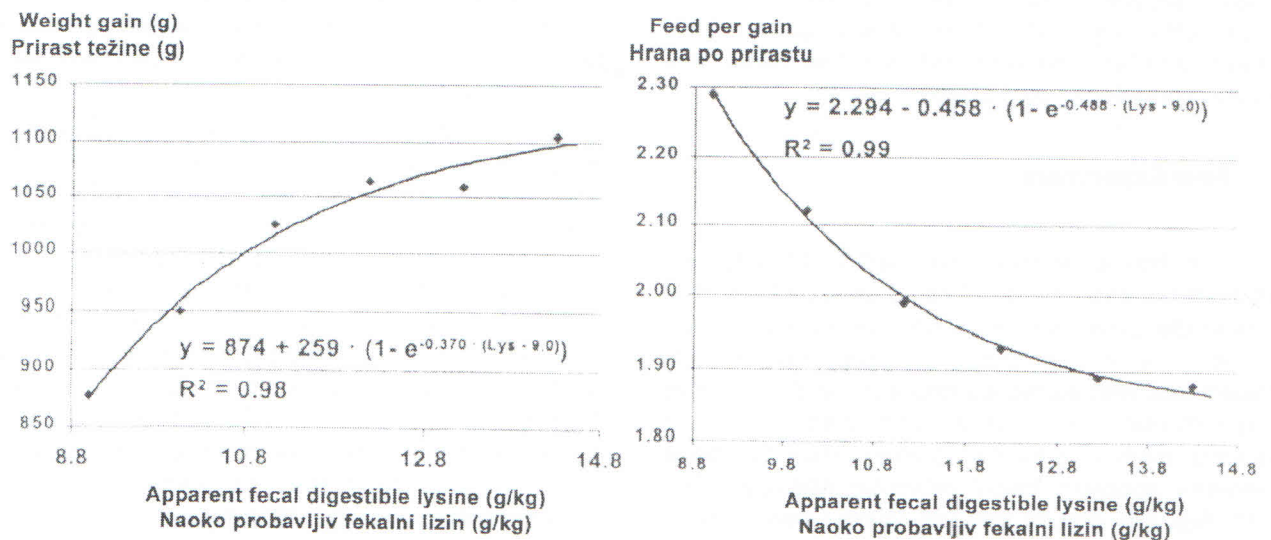


Experiment 2

In Experiment 2, graded levels of a balanced protein were fed to male Ross 508 broilers in the finisher period from day 28 to 42 (Wijten et al., 2000). The essential amino acids were increased from 92% to 146% of CVB recommendation corresponding to apparent digestible Lys levels from 9.0 to 14.3 g/kg.

Figure 3. Responses of male Ross 508 broilers 28 to 42 days of age to graded Ideal Protein levels expressed as apparent faecal digestible lysine

Slika 3. Odgovori muških Ross 508 brojlera starih 28 do 42 dana na gradirane razine idealne bjelančevine izraženi kao naoko probavljiv fekalni lizin



As in Experiment 1, birds of Experiment 2 showed enormous responses in weight gain (228 g) and feed conversion (0.41 kg/kg, Figure 2), demonstrating impressively the genetic potential of current broiler strains. According to breeder's management guide weight gain should have been 1006 g and feed per gain 1.97 kg/kg during this period (Aviagen, 1999) compared to 1105 g and 1.88 kg/kg observed at the highest IP level.

However, in contrast to the effects observed in Experiment 1 the nature of the responses in Experiment 2 is clearly non-linear. The question of the reasons behind arises. First of all, a strain effect (Ross 208 vs. 508) cannot be excluded. The start and duration of the examined periods possibly also influenced the responses. Experiment 1 started 14 days earlier and the investigated period was 7 days longer than in Experiment 2. Although knowing that ideal amino acid ratios change with age or body weight, the applied amino acid profile was not adjusted accordingly, which potentially affected the response in Experiment 2.

Additionally to weight gain and feed conversion, breast meat yield was studied in Experiment 2 (Figure 4). There was a huge response in breast meat from 372 g at the lowest to 449 g at the

highest IP level. In terms of percentage of carcass weight, breast meat yield improved by 1.1 percentage points starting already on a high level. This significant effect was linear and demonstrated clearly the sensitivity of the breast muscle to dietary amino acid supply.

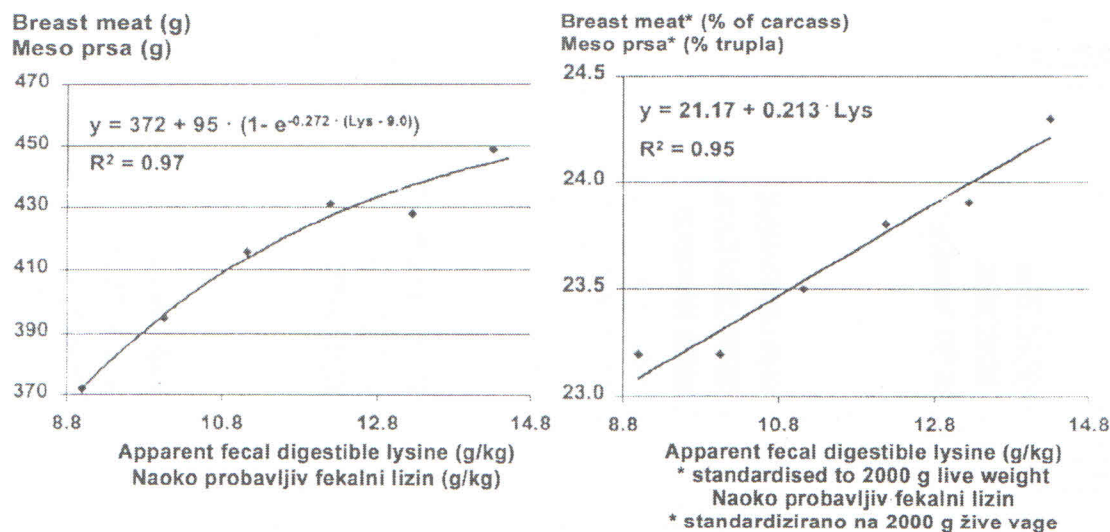
When extrapolating such findings to practical situations it must be considered that these data were generated under experimental conditions. However, there are some indications that even under practical conditions an optimised diet will lead to considerable improvements provided there are no other limiting factors.

Feeding the starter chick is crucial

Both experiments show that current broiler breeds can realise a very high performance level provided the feed is optimised according to the "Ideal Protein" concept. Both experiments were performed at different age periods. Because of the different kind of response (almost linear vs. non-linear) the question arose whether there were interactions between feeding varying levels of IP and the grow out phases. Therefore a third experiment was conducted.

Figure 3. Breast meat yield in Ross 508 broilers at day 42 fed graded Ideal Protein levels over a period of two weeks (28-42 days)

Slika 3. Prinos mesa prsa brojlera Ross 508 42. dana hranjenih klasificiranim razinama idealne bjelančevine kroz razdoblje od dva tjedna (28 do 42 dana)



Experiment 3

A total of 1440 male one day old Ross 308 chickens were assigned to 12 treatments. The experimental starter diets were fed until 14 days of age. The grower diets were fed from day 15 to 30 and the finisher diets from day 31 to 37. Two starter and two grower diets were formulated containing 100% and 120% of the lysine recommendation (CVB 1996). The finisher diets contained 90%, 100% (0.99% app. face. dig. Lys), and 110% of the lysine recommendation. The 12 treatments represented all possible combinations of different diets and the grow out phases from the lowest supply (starter: 100%, grower: 100%, finisher: 90%) to the highest supply (starter: 120%, grower: 120%, finisher: 110%). Weight gain, feed conversion, and breast meat yield were investigated.

Results are given in Figures 4. Generally, birds performed well. Thus broilers in the treatment 100-100-90 gained 2228 g, which is clearly above breeders recommendation (2082 g). The respective feed conversion was 1.60, which was lower compared to breeders recommendation (1.65). However, increased supply of amino acids over all grow out periods increased the performance substantially. Thus birds in treatment 120-120-110

achieved the highest weight gain (2327 g) and the lowest feed conversion (1.54). The performance in the other treatments was in between. The amino acid supply during starter period obviously had the strongest impact on the final weight. Birds fed the 100%-starter diets and 120%-grower diet did not achieve the performance level as observed in all treatments where birds received 120% starter diet. The magnitude of the responses to increased dietary amino acid levels in the grower and finisher diet in birds fed 100% starter diets was more pronounced compared to that observed in birds in 120% starter diet treatments. This indicates compensatory growth but, however, it was not possible to compensate for the whole depression. Feed intake and feed conversion, respectively, was a function of the dietary amino acid level. Thus, average feed per gain was higher in 120% starter - 100% grower treatments compared to 100% starter - 120% grower diet. Although numerically weight gain and feed conversion in the treatment 120% - 120% - 110% was not achieved by any of the other treatments all treatments where the broilers received 120% starter diet performed similarly. With respect to the breast meat yield the same tendency was observed. Breast meat yield increased with increasing amino acid levels and the duration.

Figure 4. Effects of various combinations of different Ideal Protein levels (% of CVB recommendation) fed in subsequent grow-out phases in broilers from 1 to 37 days of age

Slika 4. Učinci raznih kombinacija različitih razina idealne bjelančevine (% preporuke CVB) danih brojlerima od 1. do 37. dana starosti

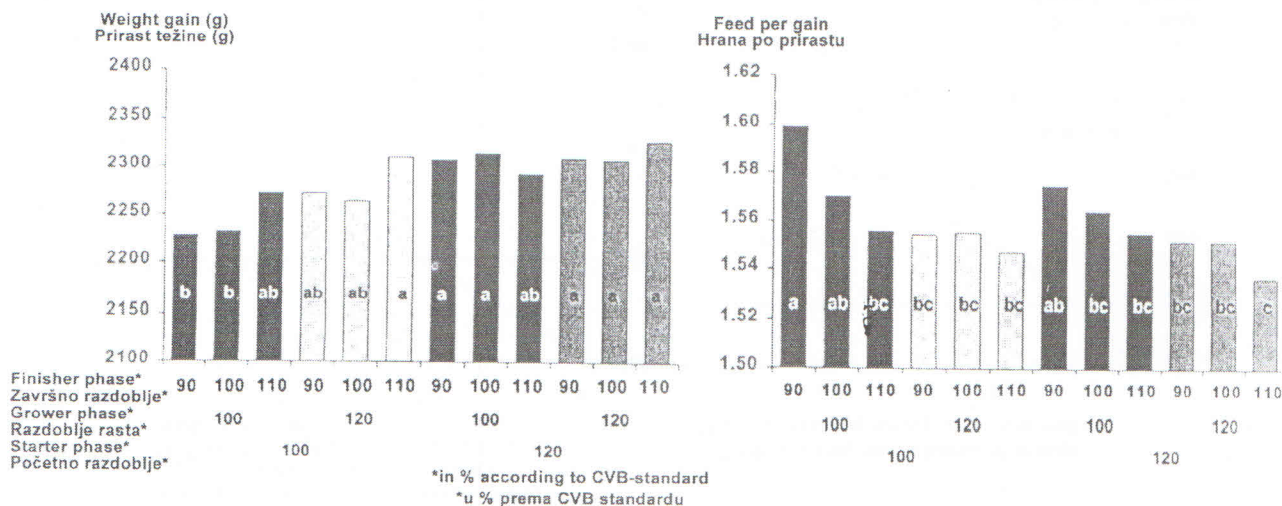
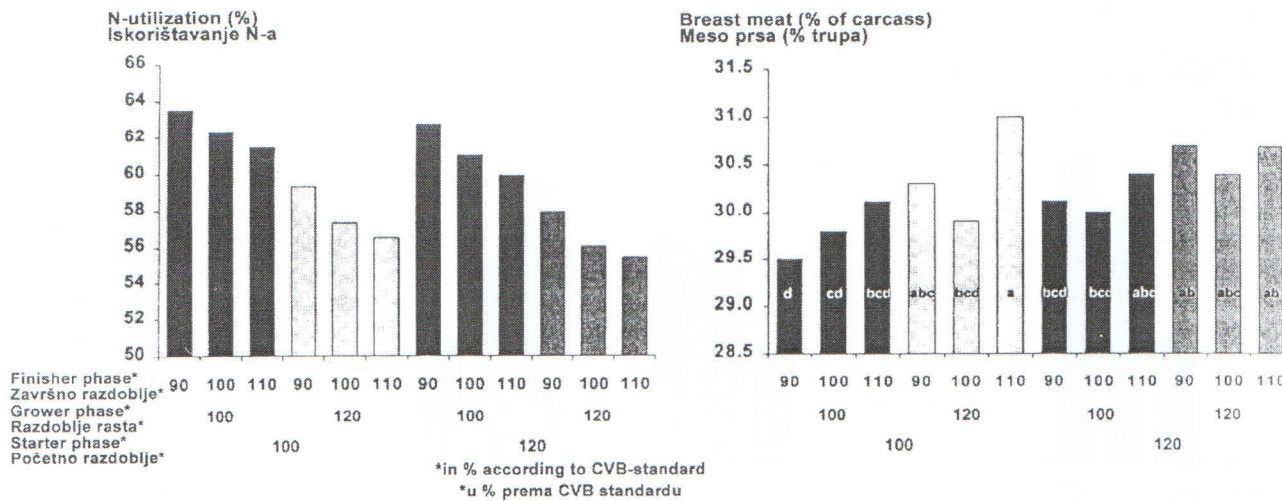


Figure 5. Effect of incremental levels of balanced amino acids on N-utilization and breast meat yield (% of carcass) fed to male broilers from day 28 to 41.

Slika 5. Učinak povećanja razine uravnoteženih amino kiselina na iskorištavanje N-a i prirast mesa prsa (% trupla) u hrani muških brojlera od 28. do 41. dana



Apart from animal performance and economic considerations ecological aspects should also be considered. The IP concept is known to increase nitrogen utilisation if utilisation of nitrogen (N) deriving from an imbalanced protein is compared to that of balanced protein. The question arises what happens when different levels of balanced protein are compared. In the present study neither N-content of the birds nor N-content of excreta were investigated. However, assuming an average N-content of 3.2% in weight gain, N-retention and utilisation can be estimated. Results are shown in Figure 5.

Costs of the high IP diets will run considerably higher compared to those with adequate amino acid levels. This would affect overall production costs especially when high IP diets are fed in the grower and finisher phase. From the economic point of view increased IP levels hence appear to be beneficial only in the starter diet since feed consumption in this period accounts to only 15% of the overall consumption. Feed conversion data underpin this conclusion. Present data suggest that especially the early stage of life is important for overall performance. The physiological background might be related to the growth and development of the gastro-intestinal tract post-hatch affecting

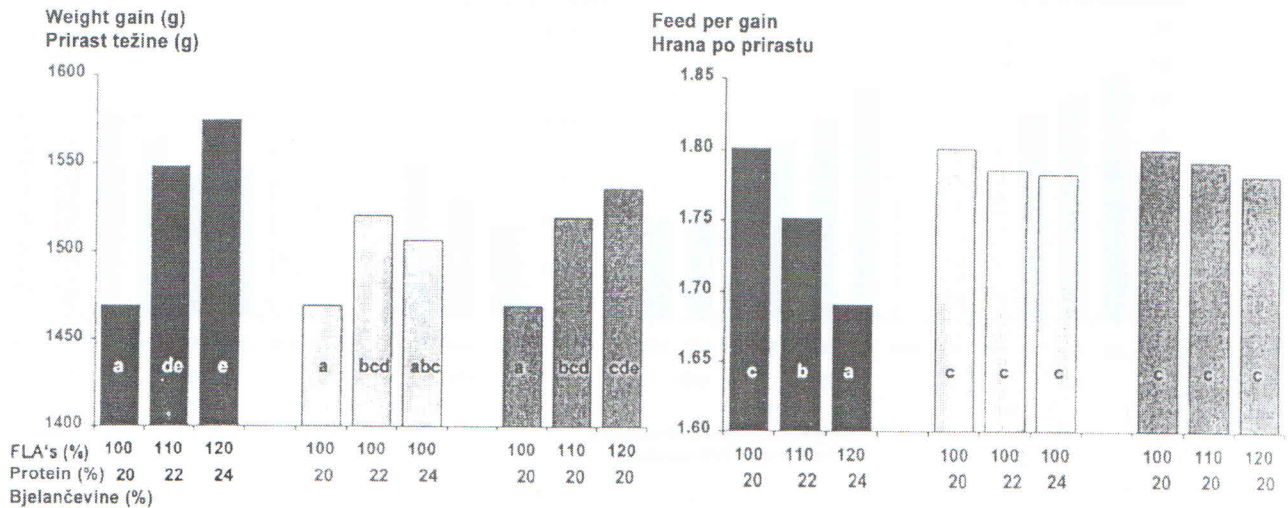
capacity and efficiency of digestion (Vieira and Moran, 1999; Ravindran, 2002).

Experiment 4

The question whether it is necessary to consider the whole range of essential amino acids or whether it is sufficient to balance only the first four (commercially available) amino acids was investigated in Experiment 4. The trial with 840 male Cobb 500 broilers comprised seven dietary treatments and ran from day 14 to 34. The "control" diet contained 20% of crude protein and 100% of recommended essential amino acids according to Schutte (1996). Based on this diet two diets were formulated where the whole range of essential and non-essential amino acids were increased up to 120% of CVB. Another two diets were formulated where Lys, Met+Cys, and Thr were maintained at 100% but crude protein was allowed to increase to 110% and 120% (22% or 24% of the diet). Finally, two diets were produced where crude protein was kept at 20% but the first limiting amino acids (FLA's) Lys, Met+Cys, and Thr were increased up to 120%.

Figure 6. Responses of male Cobb 500 broilers (14-34 days) on weight gain and feed conversion to increasing levels of first limiting amino acids (FLA's, % of CVB standard) or crude protein or both

Slika 6. Odgovori muških brojlera Cobb 500 (14 do 34 dana) na porast težine i konverziju hrane nakon povećanja razine prvih limitirajućih amino kiselina (FLA's, % CVB standarda) ili sirove bjelančevine ili i jednog i drugog

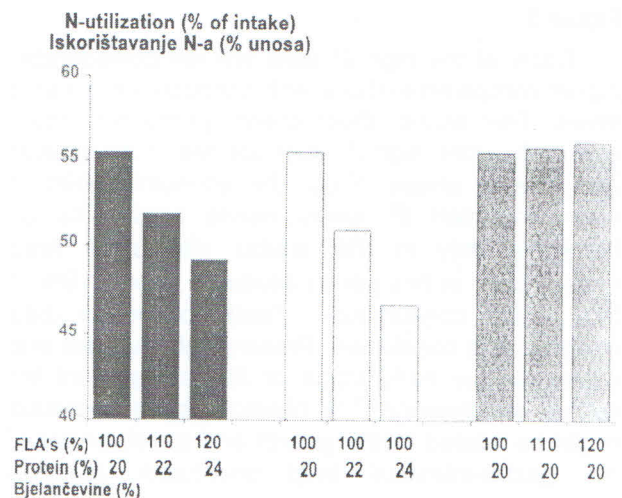


Results are shown in Figures 6 and 7. With regard to weight gain and feed conversion, the strongest effects were obtained by increasing the entire Ideal Protein. The magnitudes of these responses are almost identical to those observed in the previous experiments. With increasing crude protein but not FLA's, weight gain could not be improved above the protein level of 22%. Increasing the FLA's at maintained crude protein level resulted in a dose-dependent response. However, the performance level achieved was clearly lower compared to that when all amino acids were increased to 120%. This means that the whole range of essential amino acids has to be balanced to realise the full response potential although the FLA's account for the biggest fraction of these effects.

Nitrogen utilization results demonstrate that balancing the dietary protein according to the Ideal Protein Concept helps to reduce the adverse effects of increasing unbalanced dietary protein levels (Figure 7). However, maximum nitrogen utilization was observed when only FLA's were increased. This relationship is well known and is one of the main reasons for establishing low protein diets.

Figure 7. Responses of male Cobb 500 broilers (14-35 days) on nitrogen utilization to increasing levels of first limiting amino acids (FLA's, % of CVB standard) or crude protein or both

Slika 7. Odgovori muških brojlera Cobb 500 (14 do 35 dana) na iskorištavanje dušika nakon povećanja razine prvih limitirajućih amino kiselina (FLA's, % CVB standarda) ili sirove bjelančevine ili i jednog i drugog



Economic and ecological considerations limit the application of elevated Ideal Protein diets to starter diets

In summary, the responses observed in the five experiments suggest that the genetic potential of current broiler strains is very high and probably not a limiting factor under practical feeding conditions. Increasing the whole ideal amino acid profile substantially improved performance - not only weight gain and feed conversion, but also breast meat yield. On the other hand, nitrogen utilisation dropped dramatically with increasing IP levels. It could also be shown that male and female birds responded the same way to increased amino acid supply in the starter phase. Data obtained by the last experiment clearly demonstrate that the whole range of essential amino acids has to be considered to get the full response. However, the first limiting amino acids contribute a major portion to the potential effect.

It appears beneficial from the economical and acceptable from the ecological point of view to feed increased Ideal Protein levels to male and female broilers in the starter period, as positive effects persisted over the full production cycle.

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