RESEARCH ARTICLE

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Influence of age and type of feed ingredients on apparent and standardized ileal amino acid digestibility in broiler chickens

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Abstract

Two experiments were conducted to determine the effects of bird age on apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of amino acids (AA) for 10-d-old Experiment (Exp. 1) and 22-d-old (Exp. 2) male broilers. This study investigated the effects of different broiler ages and feed ingredients on AID and SID of AA in corn and soybean meal (SBM). Four hundred and eighty (age = 7 d; initial body weight [BW] = 173.4 ± 12.65 g) and 192 (age = 18 d; initial BW = 772.2 ± 62.13 g) birds were allocated to three dietary treatments in a randomized complete block design with eight replicate cages per treatment. Two diets were formulated based on corn or SBM as the sole source of AA in the diet. A nitrogen-free diet was also formulated to measure basal endogenous losses of AA. Experimental diets were given for 3 and 4 days in Exps. 1 and 2, respectively. An interaction was observed ($p < 0.05$) between the age of birds and the type of ingredient for the AID of most AA, except for methionine, valine, cysteine (Cys), and tyrosine; however, the effects of age and type of ingredients were diminished in the SID of AA, except for histidine, isoleucine, leucine (Leu), phenylalanine, alanine (Ala), and glutamic acid (Glu). The AID of AA, except for Leu and Cys and the SID of AA, except for Leu, Ala, Glu, and Pro in SBM were greater ($p < 0.05$) than in corn. As the age of birds increased from 10 to 22 d, digestibility of all AA increased ($p < 0.05$), regardless of the expression of AA digestibility (i.e., AID and SID). In conclusion, the AID and SID of AA in both corn and SBM increased with increasing age, and the AID and SID of AA in SBM were greater than in corn.

Keywords: Amino acid, Ileal digestibility, Corn, Soybean meal, Broiler

INTRODUCTION

Corn and soybean meal (SBM) are feed ingredients that are commonly used to fulfill the energy and amino acid (AA) requirements of poultry and account for more than 70% of broiler diets. Broilers' feed costs are highly dependent on the costs of these two major ingredients and affect demand and supply in broiler production [1]. The supplementation of diets with appropriate amounts of dietary protein and AA is directly correlated with broilers' body protein accretion and growth performance [2,3]. Diets

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: An SH, Kong C.
Data curation: An SH, Kong C.
Formal analysis: An SH.
Methodology: An SH, Kong C.
Software: An SH, Kong C.
Validation: An SH.
Investigation: Kong C.
Writing - original draft: An SH, Kong C.
Writing - review & editing: An SH, Kong C.

Ethics approval and consent to participate
The protocols for the present study were reviewed and approved by the Institutional Animal Care and Use Committee at Kyungpook National University (KNU2020-0066).

formulated with digestible AA to provide balanced dietary AA would ensure the growth of broilers [4]. Therefore, to achieve better growth performance and feed efficiency, it is important to accurately determine the digestible AA concentration in feed ingredients employed in feed formulations [5]. The standardized ileal digestibility (SID) of AA is considered as the most reliable value to obtain accurate values of the level of digestible AA in single feed ingredients or mixed diets [6,7]. Because the SID of AA is more additive in the mixed diet than the apparent ileal digestibility (AID), the SID of AA is widely used to express the digestible AA in diets for broilers [5,8,9].

The gastrointestinal integrity in broiler chickens increases with age, which improves the capability of nutrients digestion and absorption [10,11]. To accurately formulate diets to achieve appropriate amounts of nutrients for the different growth stages of broilers, the digestible AA at age-appropriate values should be used. However, there are limited data for AA digestibility values for young broilers or on comparisons of AA digestibility between broilers of different ages. Therefore, in this study, SID and AID of AA in corn and SBM for 10- and 22-d-old male broilers were determined.

MATERIALS AND METHODS

The protocols for the present study were reviewed and approved by the Institutional Animal Care and Use Committee at Kyungpook National University (KNU2020-0066).

Dietary treatments

The analyzed crude protein (CP) and AA compositions in corn and SBM used in the present study are shown in Table 1. Tables 2 and 3 present the ingredient compositions and analyzed AA compositions of the experimental diets used in experiment 1, respectively. The ingredients compositions and analyzed AA of the experimental diets used in experiment 2 are presented in Tables 4 and 5, respectively. The analyzed AA compositions in the experimental diets were close to the calculated values. A nitrogen-free diet (NFD) was formulated to estimate the basal endogenous losses (BEL) of AA. Two of three diets were formulated to contain either corn or SBM as the sole source of AA. All dietary energy and nutrient contents met or exceeded the recommended requirements for broilers, except CP and AA. All diets contained 0.5% chromic oxide as an index for calculating digestibility.

Animals and management

Two experiments were conducted. Both experiments used the same experimental design and protocol, but male boilers of different ages were used (Exp. 1: 7–10 d; Exp. 2: 18–22 d). Four hundred and eighty (age = 7 d; initial body weight [BW] = 173.4 ± 12.65 g) and 192 (age = 18 d; initial BW = 772.2 ± 62.13 g) Ross 308 broilers were allocated to the three dietary treatments in a randomized complete block design with eight replicate cages per treatment using the Experimental Animal Allotment Program [12]. In Exp. 1, from 1 to 7 d of age, all birds were fed the experimental diets *ad libitum* for 3 days. In Exp. 2, day-old birds were fed a commercial starter diet with 20% CP from d 1 to 18 days of age. Birds were provided *ad libitum* access to water and feed during the experimental periods. The experimental environment was controlled with continuous light and temperature conditions. Birds were housed in wire-floored cages in an environmentally controlled room at 33℃ for the first 3 d, and then the temperature was gradually decreased to 24℃ at d 22, in accordance with Ross broiler recommendations, after which it was maintained until the end of the experiment.

Table 1. Analyzed crude protein and amino acid compositions of corn and soybean meal (%, as-is basis)

Item	Feed ingredients	
	Corn	SBM
Crude protein	7.34	43.23
Indispensable AA		
Arg	0.45	3.11
His	0.24	1.09
Ile	0.23	1.63
Leu	0.90	3.37
Lys	0.28	2.53
Met	0.19	0.57
Phe	0.35	2.14
Thr	0.29	1.74
Val	0.34	1.70
Dispensable AA		
Ala	0.56	1.91
Asp	0.57	4.93
Cys	0.19	0.61
Glu	1.44	7.65
Gly	0.34	1.82
Pro	0.71	2.27
Ser	0.41	2.30
Tyr	0.30	1.51

SBM, soybean meal; AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

Sample collection

On 10 and 22 d in Exps. 1 and 2, all birds were euthanized by CO_2 asphyxiation. Ileal digesta was collected from the distal two-thirds of the ileum (the portion of the small intestine from Meckel's diverticulum to approximately 1 cm anterior to the ileocecal junction) by rinsing the samples with distilled water [13]. Ileal digesta samples from 20 and 8 birds within a cage for Exps. 1 and 2 were pooled, respectively. Collected ileal samples were stored in a freezer at −20℃ for further analyses.

Chemical analysis

The ingredients and experimental diet samples were dried at 135℃ for 2 h in accordance with method 930.15 of AOAC International [14] and ground using a mill grinder (CT 293 Cyclotec, Foss, Hamburg, Germany). Freeze-dried ileal digesta samples were ground using a coffee grinder. The dried samples of the ingredients, diets, and ileal digesta were analyzed for AA content using method 982.30 of AOAC International [14], except for Trp. Dried diets and ileal digesta samples were analyzed for chromium content using the method described by Fenton and Fenton [15], which was used in calculating ileal digestibility.

Calculation

The AID, BEL, and SID of the AA were calculated using the following equations from Kong and Adeola [5]:

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Table 2. Ingredient and chemical compositions (%) of diets in Experiment 1, as-fed basis

Ingredient	Experimental diets		
	Corn	Soybean meal	N-free diet
Corn	95.36	-	-
Soybean meal	-	41.24	-
Cornstarch	-	50.48	29.86
Sucrose	-	-	55.00
Soybean oil	-	4.00	4.00
Calcium phosphate (monocalcium)	2.00	1.85	2.41
Limestone, ground	1.54	1.33	1.34
Vitamin-Mineral premix[1)]	0.20	0.20	0.20
Sodium chloride	0.40	0.40	-
Chromic oxide	0.50	0.50	0.50
Cellulose	-	-	5.00
Choline chloride	-	-	0.25
Sodium bicarbonate	-	-	0.75
Potassium chloride	-	-	0.30
Magnesium oxide	-	-	0.09
Potassium carbonate	-	-	0.30
Total	100.0	100.0	100.0
Calculated composition (%)			
MEn (kcal/kg)	3,194	3,301	3,404
Crude protein	8.11	20.00	-
Ca	1.00	1.00	1.00
Non-phytate P	0.45	0.45	0.45
Total amino acids (%)			
Arg	0.36	1.48	-
His	0.22	0.55	-
Ile	0.28	0.92	-
Leu	0.95	1.59	-
Lys	0.25	1.26	-
Met	0.17	0.29	-
Met + Cys	0.34	0.60	-
Phe	0.36	1.02	-
Phe + Tyr	0.65	1.91	-
Thr	0.28	0.81	-
Trp	0.06	0.35	-
Val	0.04	0.97	-

[1)]Provided per kg of diet: vitamin A, 9,000 IU; vitamin D, 4,000 IU; vitamin E, 50 mg; vitamin K_3, 2.5 mg; thiamine nitrate, 2.0 mg; riboflavin, 6.0 mg; pyridoxine hydrochloride, 3.0 mg; vitamin B_{12}, 0.013 mg; nicotinic acid, 50.0 mg; calcium pantothenate, 15.0 mg; folic acid, 1.5 mg; biotin, 0.1 mg; Mn, 96 mg as manganese sulfate; Zn, 90 mg as zinc sulfate; Fe, 50 mg as ferrous sulfate and ferric oxide; Cu, 24 mg as cupric sulfate; I, 1.2 mg as calcium iodate; Se, 0.36 mg as sodium selenite.

MEn, nitrogen-corrected metabolizable energy; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Cys, cysteine; Phe, phenylalanine; Tyr, tyrosine; Thr, threonine; Trp, tryptophan; Val, valine.

Table 3. Analyzed amino acid composition of the experimental diets for Experiment 1 (%, as-fed basis)

Item	Dietary treatment		
	NFD	Corn	SBM
Indispensable AA			
Arg	-	0.453	1.483
His	-	0.240	0.523
Ile	-	0.243	0.883
Leu	-	0.863	1.600
Lys	-	0.287	1.230
Met	0.001	0.175	0.284
Phe	-	0.350	1.023
Thr	0.007	0.290	0.823
Val	-	0.363	0.930
Dispensable AA			
Ala	0.006	0.523	0.897
Asp	0.007	0.577	2.337
Cys	-	0.175	0.284
Glu	0.015	1.403	3.647
Gly	0.009	0.343	0.887
Pro	-	0.667	1.067
Ser	0.011	0.397	1.073
Tyr	-	0.287	0.680

NFD, nitrogen-free diet; SBM, soybean meal; AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

$$\text{AID (\%)} = 100 - [(\text{Cr}_{\text{diet}} \times \text{AA}_{\text{digesta}}) / (\text{Cr}_{\text{digesta}} \times \text{AA}_{\text{diet}})] \times 100$$
$$\text{BEL (mg/kg of dry matter intake)} = (\text{Cr}_{\text{diet}} / \text{Cr}_{\text{digesta}}) \times \text{AA}_{\text{digesta}}$$
$$\text{SID (\%)} = \text{AID} + [(\text{BEL} / \text{AA}_{\text{diet}}) \times 100]$$

where Cr_{diet} (g/kg) and $\text{Cr}_{\text{digesta}}$ (g/kg) are the chromium concentrations of the diet and digesta on a dry matter (DM) basis; and AA_{diet} (mg/kg of DM) and $\text{AA}_{\text{digesta}}$ (mg/kg of DM) are the AA concentrations of the diet and digesta on a DM basis, respectively.

Statistical analysis

Data were analyzed using the MIXED procedure in SAS software (SAS 9.4, SAS Inst, Cary, NC, USA). The experimental unit was a cage. Dietary treatments were considered as a fixed variable, and the block (replication) was considered as a random variable. The AID and SID values for corn and SBM were presented as the least squares mean. Contrasts were used to determine the main effects of age (10 vs. 22 d) and feed ingredients (corn vs. SBM) and the interaction between these two main effects. The significance was set at $\alpha = 0.05$.

RESULTS

The values for the AID of AA in corn and SBM for broilers between 10- and 22-d-old male broilers are presented in Table 6. There was an interaction ($p < 0.05$) between the age of birds (10 vs. 22 d) and feed ingredients (corn and SBM) for the AID of most AA, except for methionine (Met),

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Table 4. Ingredient and chemical compositions (%) of diets in Experiment 2, as-fed basis

Ingredient	Experimental diets		
	Corn	Soybean meal	N-free diet
Corn	94.82	-	-
Soybean meal	-	41.24	-
Cornstarch	-	49.90	28.79
Sucrose	-	-	55.00
Soybean oil	-	4.00	4.00
Calcium phosphate (monocalcium)	1.78	1.70	2.14
Limestone, ground	2.00	1.76	1.88
Vitamin-Mineral premix[1)]	0.50	0.50	1.00
Sodium chloride	0.40	0.40	-
Chromic oxide	0.50	0.50	0.50
Cellulose	-	-	5.00
Choline chloride	-	-	0.25
Sodium bicarbonate	-	-	0.75
Potassium chloride (KCl)	-	-	0.30
Magnesium oxide (MgO)	-	-	0.09
Potassium carbonate	-	-	0.30
Total	100.00	100.00	100.00
Calculated composition (%)			
MEn (kcal/kg)	3,176	3,372	3,360
Crude protein	8.06	20.00	-
Ca	1.00	1.00	1.00
Non-phytate P	0.45	0.45	0.45
Total amino acids (%)			
Arg	0.36	1.29	-
His	0.22	0.48	-
Ile	0.27	0.81	-
Leu	0.95	1.40	-
Lys	0.25	1.11	-
Met	0.17	0.26	-
Met + Cys	0.34	0.53	-
Phe	0.36	0.89	-
Phe + Tyr	0.64	1.68	-
Thr	0.27	0.71	-
Trp	0.06	0.31	-
Val	0.04	0.85	-

[1)]Provided per kg of diet: vitamin A, 9,000 IU; vitamin D, 4,000 IU; vitamin E, 50 mg; vitamin K_3, 2.5 mg; thiamine nitrate, 2.0 mg; riboflavin, 6.0 mg; pyridoxine hydrochloride, 3.0 mg; vitamin B_{12}, 0.013 mg; nicotinic acid, 50.0 mg; calcium pantothenate, 15.0 mg; folic acid, 1.5 mg; Biotin, 0.1 mg; Mn, 96 mg as manganese sulfate; Zn, 90 mg as zinc sulfate; Fe, 50 mg as ferrous sulfate and ferric oxide; Cu, 24 mg as cupric sulfate; I, 1.2 mg as calcium iodate; Se, 0.36 mg as sodium selenite.

MEn, nitrogen-corrected metabolizable energy; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Cys, cysteine; Phe, phenylalanine; Tyr, tyrosine; Thr, threonine; Trp, tryptophan; Val, valine.

valine, cysteine (Cys), and Tyr. The AID of AA, except for leucine (Leu) and Cys of birds fed a corn-based diet, was lower ($p < 0.05$) than the values of birds fed an SBM-based diet, regardless of the age of the birds. Estimated AID of indispensable AA in corn for 10- and 22-d-old male

Table 5. Analyzed amino acid composition of the experimental diets for Experiment 2 (%, as-fed basis)

Item	Dietary treatment		
	NFD	Corn	SBM
Indispensable AA			
Arg	0.012	0.36	1.21
His	0.004	0.23	0.45
Ile	0.016	0.25	0.80
Leu	0.032	0.86	1.37
Lys	0.011	0.26	1.08
Met	0.002	0.15	0.26
Phe	0.023	0.35	0.91
Thr	0.015	0.27	0.69
Val	0.029	0.37	0.87
Dispensable AA			
Ala	0.028	0.53	0.77
Asp	0.036	0.50	1.96
Cys	0.003	0.17	0.24
Glu	0.053	1.36	3.16
Gly	0.019	0.31	0.74
Pro	-	0.64	0.88
Ser	0.017	0.34	0.85
Tyr	0.012	0.22	0.58

NFD, Nitrogen-free diet; SBM, soybean meal; AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

broilers ranged from 49.4% (threonine [Thr]) to 80.5% (Met) and 68.2% (Thr) to 89.9% (Leu), respectively. In addition, estimated AID of indispensable AA in SBM for 10- and 21-d-old male broilers ranged from 73.5% (Thr) to 88.0% (arginine [Arg]) and 81.2% (Thr) to 92.2% (Arg), respectively. The estimated AID of all AA for 22-d-old male broilers was greater ($p < 0.05$) than the values for 10-d-old male broilers, regardless of the type of feed ingredient. Table 7 presents the BEL of AA for 10- and 22-d-old male broilers fed NFD. The BEL values of all indispensable and dispensable AA values for 10-d-old broilers were greater ($p < 0.05$) than those for 22-d-old birds.

The SID of AA values in corn and SBM for 10- and 22-d-old male broilers are presented in Table 8. For the SID of AA, there was an interaction ($p < 0.05$) for only histidine, isoleucine, Leu, phenylalanine, alanine (Ala), and glutamic acid (Glu) values between the age of the birds and ingredients. The trends of the effect of age on the AA digestibility were maintained and the effect of ingredients on AA digestibility were similar to the AID of AA values. The SID of AA, except for Leu, Ala, Glu, and proline, in corn were lower ($p < 0.05$) than the values in SBM, regardless of age. The estimated SID of indispensable AA in corn for 10- and 22-d-old male broilers ranged from 71.8% (Thr) to 86.0% (Met) and 81.8% (Lys) to 92.8% (Leu), respectively. In addition, estimated SID of indispensable AA in SBM for 10- and 21-d-old male broilers ranged from 81.4% (Thr) to 89.8% (Arg) and 86.8% (Thr) to 93.4% (Arg), respectively. Similar to the result of the AID of AA, the estimated SID of all AA for 22-d-old male broilers was also greater ($p < 0.05$) than the values for 10-d-old male broilers, regardless of the type of feed ingredient.

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Table 6. Apparent ileal digestibility (%) of amino acids in the corn- or soybean meal-based diet fed to 10-d-old and 22-d-old broiler chickens[1)]

Item	Corn		SBM		SEM	*p*-values		
	d 10	d 22	d 10	d 22		Age	Ingredient	Age × Ingredient
Indispensable AA								
Arg	79.6	87.0	88.0	92.2	0.55	< 0.01	< 0.01	0.007
His	76.2	86.1	83.3	88.1	0.80	< 0.01	< 0.01	0.004
Ile	68.0	81.9	82.7	88.0	0.86	< 0.01	< 0.01	<0.01
Leu	79.7	89.9	83.6	88.4	0.63	< 0.01	0.072	<0.01
Lys	66.0	76.0	84.4	88.1	0.98	< 0.01	< 0.01	0.003
Met	80.5	87.9	85.9	91.6	0.60	< 0.01	< 0.01	0.167
Phe	74.9	85.7	83.7	88.2	0.73	< 0.01	< 0.01	0.000
Thr	49.4	68.2	73.5	81.2	1.39	< 0.01	< 0.01	0.001
Val	72.8	76.9	82.6	83.7	1.01	0.016	< 0.01	0.134
Dispensable AA								
Ala	76.5	87.3	81.3	86.4	0.79	< 0.01	0.020	0.001
Asp	65.8	77.9	77.7	83.9	1.00	< 0.01	< 0.01	0.007
Cys	65.0	78.7	62.9	76.9	1.18	< 0.01	0.113	0.941
Glu	80.6	89.7	85.4	89.8	0.60	< 0.01	< 0.01	0.001
Gly	62.0	73.7	74.9	81.4	1.15	< 0.01	<0.01	0.030
Pro	75.7	84.5	80.2	85.2	0.78	< 0.01	0.002	0.021
Ser	64.5	77.5	77.5	85.2	1.06	< 0.01	< 0.01	0.020
Tyr	74.3	80.8	83.2	88.1	0.82	< 0.01	< 0.01	0.337

[1)]Data are least squares means of eight observations per treatment.

SBM, soybean meal; AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

DISCUSSION

Several studies demonstrated that the utilization of nutrients can be influenced by the age of birds [10,11,16] In addition, the digestible AA varies on the feed ingredients [17,18]. Therefore, the determination of AA digestibility of broilers in different growth stages can help formulate accurate feed formulation with digestible AA of birds. The aim of the present study was to evaluate the AA digestibility of corn and SBM in different ages of broilers commonly used in poultry diet.

Similar trends were observed in the SID of AA in corn and SBM in response to the age of the birds. However, the impact of age on AID and SID of corn was greater than that of SBM, which might be attributable to the low absolute amount of digestible AA due to the low AA concentration in corn and low feed intake in young broilers. The discrepancy in AA digestibility among ingredients diminished with advancing age of the birds, which might be attributable to the greater contribution of BEL of AA in corn than that of SBM, and greater amounts of BEL in younger than in older birds [19,20]. A greater contribution of BEL in diet with a low level of CP (i.e., corn) than in that with a high level of CP (i.e., SBM) is well accepted in various studies [6,7]. For this reason, a reduced interaction effect in the SID of AA is partially explained by the reduced contribution and amount of BEL of AA in the test ingredients with age.

In the present study, the AID and SID of AA in corn and SBM improved as the age of the chickens increased. The ileal AA digestibility was higher in 22-d-old than in 10-d-old birds. Huang et al. [11] reported the AID of AA in corn and SBM for 14-, 28-, and 42-d-old broilers. In their study, the ranges of average AID of AA in corn and SBM for 14- and 28-d-old broilers

Table 7. Basal endogenous losses (mg/kg of DMI) of amino acids in broilers fed nitrogen-free diet at 10 and 22 days of age[1)]

Item	Basal endogenous losses of AA		SE	*p*-value
	d 10	d 22		
Indispensable AA				
Arg	273[a]	105[b]	12.8	< 0.01
His	122[a]	63[b]	4.7	< 0.01
Ile	320[a]	147[b]	8.4	< 0.01
Leu	461[a]	210[b]	17.0	< 0.01
Lys	263[a]	126[b]	15.0	< 0.01
Met	96[a]	42[b]	4.1	< 0.01
Phe	235[a]	147[b]	9.9	< 0.01
Thr	649[a]	315[b]	13.6	< 0.01
Val	292[a]	231[b]	12.7	< 0.01
Dispensable AA				
Ala	292[a]	168[b]	12.5	< 0.01
Asp	694[a]	319[b]	28.0	< 0.01
Cys	214[a]	105[b]	7.2	< 0.01
Glu	743[a]	357[b]	29.1	< 0.01
Gly	348[a]	189[b]	12.9	< 0.01
Pro	405[a]	252[b]	11.0	< 0.01
Ser	555[a]	252[b]	13.7	< 0.01
Tyr	254[a]	105[b]	6.3	< 0.01

[1)]Values were determined using the pooled samples from eight replicate cages of 20 and 5 birds per cage for 10- and 21-d-old male broiler chickens.

[a,b]Least squares means within a row without a common superscript differ ($p < 0.05$).

DMI, dry matter intake; AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

were 79.0% to 83.3% and 85.1% to 87.9%, respectively. These values are close to those obtained in the present study. Several researchers have found that the digestibility of protein and AA is age-dependent [11,16,17,21]. The availability of dietary energy [16], protein, and AA [11,16,17,21] is lower in newly hatched birds (from 1- to 10-d-old) than that in mature ones. Increased digestibility of AA with age might be explained by improved digestive enzyme activities [10,22,23]; increased AA absorption results in morphological development of the digestive tract [10,22,24]. In previous studies, the activities of intestinal lipase, pancreatic amylase and lipase, trypsin, and intestinal amylase were found to peak at 4, 8, 11, and 17 d old, respectively [22]. In addition, Noy and Sklan [10] reported increased activities of digestive enzymes, including amylase, trypsin, and protease, between 4 and 21 d of age. Using a broken-line analysis, Batal and Parsons [16] found that total tract digestibility of energy and Lys of birds peaked at 14 and 10 d of age, respectively.

In the present study, the values of AID of AA in corn and SBM in 10- and 22-d-old birds were low for Thr (49.4% and 68.2% in corn and SBM for 10 d of age; 73.5% and 81.2% in corn and SBM for 21 d of age) and high for Met (80.5% and 87.9% for 10 d) and Arg (88.0% and 92.2% for 21 d), respectively. Although the availability of dietary AA increased with advancing age of birds, similar results have been reported by previous studies [6–8,25]. The composition of protein and AA in feed ingredients varies with the plant origin of the feed ingredient. Thus, the effect of the age of birds on AA digestibility may reasonably be influenced by the nutritional composition of the feed

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Table 8. Standardized ileal digestibility (%) of amino acids in the corn- or soybean meal-based diet fed to 10-d-old and 22-d-old broiler chickens[1)]

Item	Corn		SBM		SEM	*p*-values		
	d 10	d 22	d 10	d 22		Age	Ingredient	Age × Ingredient
Indispensable AA								
Arg	85.7	91.3	89.8	93.4	0.55	< 0.01	< 0.01	0.082
His	81.3	89.5	85.6	89.8	0.80	< 0.01	0.008	0.018
Ile	81.1	88.6	86.3	90.1	0.86	< 0.01	< 0.01	0.038
Leu	85.1	92.8	86.5	90.2	0.63	< 0.01	0.362	< 0.01
Lys	75.1	81.8	86.5	89.5	0.98	< 0.01	< 0.01	0.060
Met	86.0	91.1	89.3	93.5	0.60	< 0.01	< 0.01	0.438
Phe	81.6	90.7	86.0	90.1	0.73	< 0.01	0.017	< 0.01
Thr	71.8	82.7	81.4	86.8	1.39	< 0.01	< 0.01	0.056
Val	80.8	85.3	85.8	87.2	1.01	0.006	< 0.01	0.140
Dispensable AA								
Ala	82.1	91.1	84.6	89.0	0.79	< 0.01	0.816	0.007
Asp	77.8	85.5	80.6	85.8	1.00	< 0.01	< 0.01	0.215
Cys	77.2	85.8	70.5	81.9	1.18	< 0.01	< 0.01	0.239
Glu	85.9	92.8	87.5	91.1	0.60	< 0.01	0.922	0.011
Gly	72.1	80.7	78.8	84.3	1.15	< 0.01	< 0.01	0.191
Pro	81.8	89.0	84.0	88.5	0.78	< 0.01	0.271	0.087
Ser	78.5	86.2	82.7	88.7	1.06	< 0.01	< 0.01	0.425
Tyr	83.1	87.8	86.9	90.8	0.82	< 0.01	< 0.01	0.637

[1)]Data are least squares means of eight observations per treatment.

AA, amino acids; Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; Val, valine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; Glu, glutamic acid; Gly, glycine; Pro, proline; Ser, serine; Tyr, tyrosine.

ingredients, the presence of antinutritional factors, and different processing methods. Huang et al. [11] compared the effects of age on the AID of AA in eight feed ingredients (wheat, sorghum, corn, SBM, canola meal, cottonseed meal, meat and bone meal, and mill run) used for poultry diets. The AA digestibility in most feed ingredients, except for cottonseed meal, showed increments with the advancing age of birds [11]. The processing of cottonseed meal, including heat and extraction treatments and the presence of an antinutritional factor, such as gossypol, alters the chemical composition of feed ingredients, resulting in nondigestible AA that cannot be broken down by digestive enzymes [11,20]. This indicates that, despite the improvements in digestive function with age, chemical and physical properties of feed ingredients still influence digestible individual AA in feed ingredients. However, in this study, the impact of the age of birds (10- and 21-d-old) was greater than that of the type of feed ingredients (in this case, corn and SBM) on the ileal AA digestibility of male broilers.

In conclusion, with advancing age of the birds, there was an increase in digestible AA concentration in corn and SBM. Our findings suggest that the levels of ileal AA digestibility in corn and SBM commonly used in poultry diets are influenced by the age of the birds and the characteristics of the feed ingredients.

REFERENCES

1. Pothidee A, Allen AJ, Hudson D. Impacts of corn and soybean meal price changes on the demand and supply of U.S. broilers. Presentation session presented at: American Agricultural

Economics Association (AAEA) Annual Meeting; 1999 Aug 8-11; Nashville, TN.
2. Jackson S, Summers JD, Leeson S. Effect of dietary protein and energy on broiler performance and production costs. Poult Sci. 1982;61:2232-40. https://doi.org/10.3382/ps.0612232
3. Pesti GM. Impact of dietary amino acid and crude protein levels in broiler feeds on biological performance. J Appl Poult Res. 2009;18:477-86. https://doi.org/10.3382/japr.2008-00105
4. Kidd MT, Tillman PB. Key principles concerning dietary amino acid responses in broilers. Anim Feed Sci Technol. 2016;221:314-22. https://doi.org/10.1016/j.anifeedsci.2016.05.012
5. Kong C, Adeola O. Evaluation of amino acid and energy utilization in feedstuff for swine and poultry diets. Asian-Australas J Anim Sci. 2014;27:917-25. https://doi.org/10.5713/ajas.2014.r.02
6. Kong C, Adeola O. Additivity of amino acid digestibility in corn and soybean meal for broiler chickens and White Pekin ducks. Poult Sci. 2013;92:2381-8. https://doi.org/10.3382/ps.2013-03179
7. An SH, Sung JY, Kang HK, Kong C. Additivity of ileal amino acid digestibility in diets containing corn, soybean meal, and corn distillers dried grains with solubles for male broilers. Animals. 2020;10:933. https://doi.org/10.3390/ani10060933
8. Adedokun SA, Adeola O, Parsons CM, Lilburn MS, Applegate TJ. Standardized ileal amino acid digestibility of plant feedstuffs in broiler chickens and turkey poults using a nitrogen-free or casein diet. Poult Sci. 2008;87:2535-48. https://doi.org/10.3382/ps.2007-00387
9. Cowieson A, Sorbara JO, Pappenberger G, Abdollahi MR, Roos FF, Ravindran V. Additivity of apparent and standardized ileal amino acid digestibility of corn and soybean meal in broiler diets. Poult Sci. 2019;98:3722-8. https://doi.org/10.3382/ps/pez060
10. Noy Y, Sklan D. Digestion and absorption in the young chick. Poult Sci. 1995;74:366-73. https://doi.org/10.3382/ps.0740366
11. Huang KH, Ravindran V, Li X, Bryden WL. Influence of age on the apparent ileal amino acid digestibility of feed ingredients for broiler chickens. Br Poult Sci. 2005;46:236-45. https://doi.org/10.1080/00071660500066084
12. Kim BG, Lindemann MD. A spreadsheet method for experimental animal allotment. J Anim Sci. 2007;85:112.
13. Kluth H, Mehlhorn K, Rodehutscord M. Studies on the intestine section to be sampled in broiler studies on precaecal amino acid digestibility. Arch Anim Nutr. 2005;59:271-9. https://doi.org/10.1080/17450390500217058
14. AOAC [Association of Official Analytical Chemists] International. Official methods of analysis of AOAC International. 18th ed. Gaithersburg, MD: AOAC International; 2005.
15. Fenton TW, Fenton M. An improved procedure for the determination of chromic oxide in feed and feces. Can J Anim Sci. 1979; 59:631-4. https://doi.org/10.4141/cjas79-081
16. Batal AB, Parsons CM. Effects of age on nutrient digestibility in chicks fed different diets. Poult Sci. 2002;81:400-7. https://doi.org/10.1093/ps/81.3.400
17. Blok MC, Dekker RA. Table ‘standardized ileal digestibility of amino acids in feedstuffs for poultry’. Wageningen: Wageningen Livestock Research; 2017. Report No.: CVB documentation report; nr. 61.
18. An SH, Kong C. Standardized ileal digestibility of amino acids in feed ingredients for broiler chickens. Korean J Poult Sci. 2020;47:135-42. https://doi.org/10.5536/KJPS.2020.47.3.135
19. Adedokun SA, Parsons CM, Lilburn MS, Adeola O, Applegate TJ. Endogenous amino acid flow in broiler chicks is affected by the age of birds and method of estimation. Poult Sci. 2007;86:2590-7. https://doi.org/10.3382/ps.2007-00096
20. Szczurek W, Świątkiewicz S. Standardised ileal amino acid digestibility in field pea seeds of

 https://doi.org/10.5187/jast.2022.e43

two cultivars differing in flower colour for broiler chickens: effects of bird age and microbial protease. Animals. 2020;10:2099. https://doi.org/10.3390/ani10112099
21. de Lima MB, Rabello CBV, da Silva EP, Lima RB, de Arruda EMF, Albino LFT. Effect of broiler chicken age on ileal digestibility of corn germ meal. Acta Sci Anim Sci. 2012;34:137-41. https://doi.org/10.4025/actascianimsci.v34i2.11812
22. Krogdahl Å, Sell JL. Influence of age on lipase, amylase, and protease activities in pancreatic tissue and intestinal contents of young turkeys. Poult Sci. 1989;68:1561-8. https://doi.org/10.3382/ps.0681561
23. Nitsan Z, Ben-Avraham G, Zoref Z, Nir I. Growth and development of the digestive organs and some enzymes in broiler chicks after hatching. Br Poult Sci. 1991;32:515-23. https://doi.org/10.1080/00071669108417376
24. Uni Z, Noy Y, Sklan D. Posthatch changes in morphology and function of the small intestines in heavy- and light-strain chicks. Poult Sci. 1995;74:1622-9. https://doi.org/10.3382/ps.0741622
25. Ravindran V, Hew LI, Ravindran G, Bryden WL. A comparison of ileal digesta and excreta analysis for the determination of amino acid digestibility in food ingredients for poultry. Br Poult Sci. 1999;40:266-74. https://doi.org/10.1080/00071669987692