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SOURCES OF VARIANCE OF ENERGY DIGESTIBILITY IN CORN-SOY POULTRY DIETS AND THE EFFECT ON PERFORMANCE: STARCH, PROTEIN, OIL AND FIBER

IZVORI VARIJANCE PROBAVLJIVOSTI ENERGIJE U OBROCIMA KUKURUZ - SOJA ZA PERAD I DJELOVANJE NA PERFORMANSU: ŠKROBA, BJELANČEVINA, ULJA I VLAKNINE

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SUMMARY

Broiler diets were formulated for 93 corn batches, each divided in half and one supplemented with xylanase, amylase and protease enzymes (Avizyme™ 1502, Danisco Animal Nutrition). Feed conversion ratio (FCR) ranged between 1.43 and 2.67. Average = 1.81, s.d. = 0.30. Weight ranged between 680 and 1301 g. Average = 909, s.d. = 114. Enzyme addition improved FCR to 1.73 and reduced variance by 30% ($P < 0.01$). Corn and digesta samples were analysed for starch, protein, oil, and gross energy content, and ileal digestible energy (IDE) averaged 2831 kcal/kg (s.d. 486 kcal/kg). Digestibility of starch, protein, oil and other fractions (fiber, etc.) were found to be 86%, 82%, 90% and 12%, respectively. With enzyme addition, IDE was raised by an average of 5% to 2975 kcal/kg, and digestibility coefficients were raised to 91%, 83%, 91%, and 14% for starch (+5%), protein (+1%), oil (+1%) and other sources (+2%), respectively.

INTRODUCTION

Corn quality is affected by genetics, growing and harvesting conditions, drying process, and feed manufacturing. Variability in composition and quality affects the metabolizable energy content with consequential effects on poultry performance. Not all the energy of the carbohydrate, oil, and protein in the corn is metabolizable. Corn (see Figure 1) is comprised of a pericarp (P) which is the outer covering, or hull, that protects the kernel from the environment, insects and pathogens, but the tip cap (T) may provide access into the kernel. The kernel is comprised of the endosperm (E) and the germ (G). The endosperm is the source of energy for the seed, from starch, and some protein. The germ, the living part of the kernel, contains enzymes, vitamins, minerals and the genetic information for the kernel to grow into a corn plant. Depending on the genetic variety, approximately 25% of the germ is corn oil, high linoleic acid. On average, the composition of corn dry matter is 68% starch, 8% protein, 4% oil, 2.5% cellulose, and trace amounts of vitamins and minerals.

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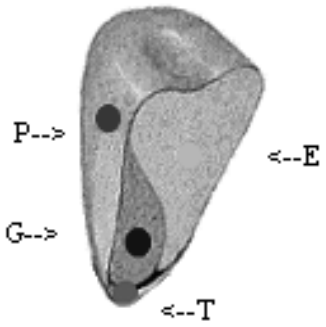
Figure 1. Corn kernel
Slika 1. Zrno kukuruza

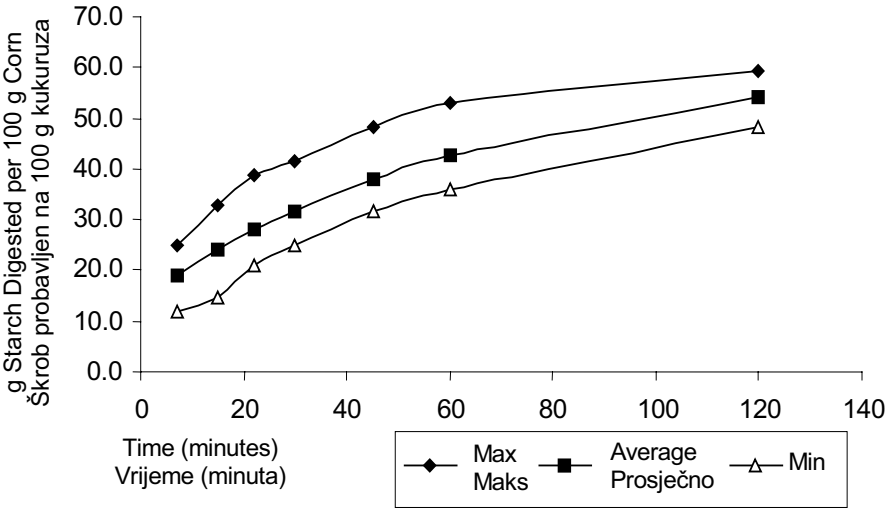


MATERIALS AND METHODS

A global corn quality survey (D'Alfonso and McCracken, 2002) provides data on the variability of corn composition. The Megazyme™ assay was used to measure starch. Protein was estimated by measuring nitrogen, and oil by ether extraction with hydrolysis. The amount of energy is relatively constant in corn oil, corn starch and corn protein: 9300, 4150, and 5490 kcal/kg, respectively (Noblet, 2000). These values correlated with gross energy of the corn with an R^2 of 92% (RMSE = +/- 0.5%). Other constants typically used for carbohydrates (4000 kcal/kg), protein (4000 kcal/kg) and fat (9000 kcal/kg) did not fit the gross energy data as well. The best-fit coefficients are also related to the method of analysis. For example, free sugar is often missed in the starch assay, leading to an underestimate of the energy from carbohydrates. Likewise, the oil assay, particularly if it does not include previous hydrolysis, could also lead to an under-estimate of the amount of oil, so the estimate of the amount of energy in oil may also be higher. Starch, protein and oil digestibility were estimated with least-square estimators on data from the 93 feed samples. The rate of starch digestion (RSD) was measured *in-vitro* in a 2 stage process in which the sample was incubated with a solution of pepsin with HCl, followed by pancreatin digestion. This process was designed to simulate digestion in the chicken (D'Alfonso and McCracken, 2002). Sub-samples were taken at 7, 15, 22, 30, 45, 60 and 120 minutes (see Figure 2). Digestibility of starch measured *in-vivo* was compared to the RSD.

Corn samples were ground and one mash broiler diet was formulated with 55% corn for each corn batch. Diet formulation is shown in Table 1. Each diet was separated into two portions and one was supplemented with a commercial enzyme blend of xylanase, amylase and protease (Avizyme™ 1502, Danisco Animal Nutrition). Diets were fed to 25 male broilers per pen from days 1-28 and body weights and feed intake were measured. Digesta samples were collected at the terminal ileum from six birds per pen and digesta from each bird were analysed for energy content. Corn samples were analysed for starch, protein, oil and gross energy content. IDE was computed using the relative proportion of titanium dioxide marker in the feed and digesta.

Figure 2. Amount of starch digested *in vitro* up to 120 minutes
Slika 2. Količina škroba probavljena *in vitro* do 120 minuta



Krmiva 47 (2005), Zagreb, 2; 83-86

Table 1. Diet.[1]
Tablica 1. Obrok[1]

Ingredient - Sastojak	(%)
Corn - Kukuruz	54.84
Soybean meal - Sojina sačma (49%)	36.34
Fishmeal - Riblje brašno	1.07
Lysine - Lizin	0.02
Dl methionine - Dl metionin	0.24
Soy oil - Sojino ulje	3.60
Dicalcium phosphate - Dikalcij fosfat	1.82
Limestone - Vapnenac	1.22
Salt - Sol	0.32
Sodium bicarbonate - Soda bikarbona	0.10
Vitamin/mineral mix Mješavina vitamina/minerala	0.27
Choline chloride - Kolin klorid	0.04
Titanium dioxide - Titanij dioksid	0.30

[1] Formulated to 23% protein, 3090 kcal/kg, 1.04% Ca, 0.776% P (0.49% available), 6.2% fat, 2.6% fiber, 0.16% Na, 0.25% Cl, 0.6% methionine, 0.98% TSAA, and 1.29% lysine.

[1] Sastavljeno na 23% bjelančevina, 3090 kcal/kg, 1,04% Ca, 0,776% P (0,49% dostupno), 6,2% masti, 2,6% vlaknine, 0,16% Na, 0,25% Cl, 0,6% methionin, 0,98% TSAK (ukupne sumporne amino kiseline), i 1,29% lizina.

RESULTS AND DISCUSSION

The performance of broilers fed different sources of corn without enzymes was variable. Feed conversion ratio (FCR) ranged between 1.43 and 2.67. Mean = 1.81, s.d. = 0.30 (CV = 16%). One outlier with FCR = 3.36 was removed from the analysis, this being a corn sample from France with 25% moisture. The weight gain ranged between 680 and 1301 g (outlier of 375 g removed). Average = 909, s.d. = 114 (CV = 13%). The addition of enzymes improved FCR to 1.73 ($P < 0.01$) and significantly reduced variance of FCR by 30% to 0.20 g feed / g gain ($P < 0.01$). Gain was not significantly affected (mean = 915 g).

Dry matter composition of the corn samples is contained in Table 2, and the outlier sample (dry matter = 75%) was removed from the analysis.

Table 2. Dry mater composition of corn samples
Tablica 2. Sadržaj suhe tvari u uzorcima kukuruza

	Dry matter Suha tvar (%)	Starch Škrob (%)	Protein Bjelan-čevina (%)	Oil Ulje (%)	Gross energy Bruto energija (kcal/kg)
Mean Sredina	89.1	68.8	8.1	4.4	4523
sd	0.87	1.8	0.7	0.6	27
Min	87.4	65.8	7.1	3.5	4474
Max	90.7	72.0	9.7	5.9	4595
CV	1%	3%	9%	13%	1%

The ileal digestible energy was measured and partitioned into starch, protein, oil and other sources. The first step of this process was to measure the dry matter percent of each of these fractions, assign appropriate energy values of 9300, 4150, 5490, and 4340 kcal/kg for oil, starch, protein and the other sources, and then to compare to the measured gross energy (GE) of the corn. An example is provided in Table 2. The measured GE for this sample was 4534 kcal/kg. The root mean square error of this method was +/- 25 kcal/kg (+/- 0.5% of the mean) and the model is highly significant ($P < 0.0001$).

Table 3. Sources of gross energy for an example corn
Tablica 3. Izvori bruto energije za uzorak kukuruza

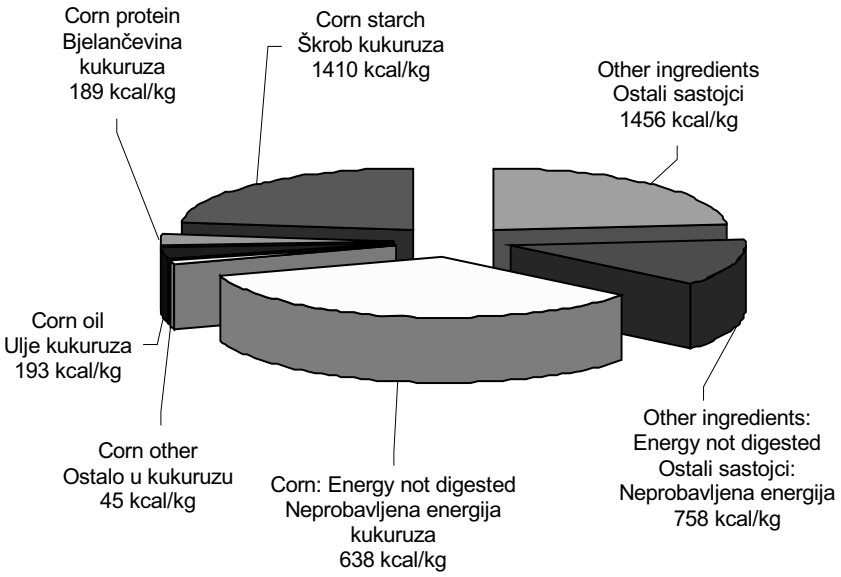
	Percent Postotak (dry - suho)	GE Bruto en. kcal/kg	kcal / kg of corn kcal/kg kukuruza
Starch Škrob	71.6	4150	2970
Protein Bjelančevina	7.7	5490	421
Oil Ulje	4.2	9300	389
Other Ostalo	16.6	4340	720
Total Ukupno	100.0		4500

The average ileal digestible energy of corn was 3246 kcal/kg DM with a standard deviation of 487 kcal/kg DM. Using least-square estimators,

digestibility coefficients for starch, protein, oil and other fractions were found to be 86.3%, 81.6%, 90.2% and 11.4%, respectively. Figure 3 illustrates the sources of variance of IDE in an example corn-soy diet (55% corn) whose GE is 4689 kcal/kg, with corn GE of 4500 kcal/kg and corn IDE of 3340 kcal/kg. With the addition of enzymes, the IDE was raised by an average of 5% to 3405 kcal/kg DM. Digestibility coefficients were found to be raised to 91.3%, 82.4%, 90.7%, and 13% for starch (+5.0%), protein (+0.8%), oil (+0.5%) and other (+1.6%), respectively. For the example in Figure 3, corn starch IDE was raised by 149 kcal/kg, protein by 2 kcal/kg, oil by 3 kcal/kg and other (fiber, etc.) by 12 kcal/kg. In a diet containing 55% corn, 91 kcal/kg was gained (0.55*166 kcal/kg) from the corn. IDE from other ingredients (e.g. soy) was raised an average 7 kcal/kg.

Figure 3. Sources of variance of digestible energy in a corn-soy diet. Total gross energy = 4689 kcal/kg.

Slika 3. Izvori varijance probavljive energije u obroku od kukuruza-soje. Ukupna bruto energija = 4689 kcal/kg



Digestibility of starch was significantly related to the RSD measured in-vitro ($P < 0.01$). While RSD ranged from 37% to 53%, with an average of 42%, digestibility of starch ranged from 84% to 90% with an average of 86%. The addition of the enzymes increased the rate of starch digestion proportionally to the improvement in IDE. It is proposed that xylanase and protease act to increase accessibility to the starch, and amylase increases the rate of starch digestion.

REFERENCES

1. D'Alfonso, T. H., K. McCracken (2002): Global corn quality variability. *Proceedings of the Multistate Poultry Meeting*, Indianapolis, Indiana, May14-16.
2. Noblet, J. (2002): Digestive and metabolic utilization of energy in swine: application to energy evaluation systems. *Journal of Applied Animal Research* 17: 113-132.

SAŽETAK

Obroci za brojlere sastavljeni su za 93 porcije kukuruza od kojih je svaka raspolovljena a jednoj su dodani enzimi, ksilanaze, amilaze i proteaze (Avizyme™ 1502, Danisco Nutrition). Omjer konverzije hrane (FCR) kretao se između 1.33 i 2.67. Prosjek = 1.81, s.d. = 0.30. Težina se kretala između 680 i 1301 g. Prosjek = 909, s.d. = 114. Dodatak enzima poboljšao je FCR na 1.73 i smanjio varijancu za 30% ($P< 0.01$). Uzorci kukuruza i digeste analizirani su za škrob, bjelančevinu, ulje i sadržaj bruto energije a ilealna probavljiva energija (IDE) prosječno je iznosila 2831 kcal/kg (s.d. 486 kcal/kg). Probavljivost škroba, bjelančevine, ulja i drugih frakcija (vlaknina, itd.) iznosila je 86%, 82%, 90% odnosno 12%. S dodatkom enzima IDE je porastao za prosječno 5% do 2975 kcal/kg a koeficijenti probavljivosti porasli su na 91%, 83%, 91% i 14% za škrob (+5%), bjelančevinu (+ 1%), ulje (+ 1%) i druge izvore (+ 2%).