Influence of the corn endosperm type on the *in vitro* starch digestion rate in the small intestine of broiler chickens

D. Grbesa[*]*, B. Homen and G. Kis, Faculty of Agriculture, University of Zagreb, 10000 Zagreb, Svetosimunska 25, Croatia, E-mail: dgrbesa@agr.hr*

Abstract

The objective of this study was to investigate differences among twelve commercial corn hybrids in the proportion of horny and floury endosperm and i*n vitro* kinetics of starch digestion in the small intestine of broiler chicken. *In vitro* starch digestion procedure simulates the consecutive digestion processes in the different parts of the small intestine of the broiler. The overall content of horny endosperm was ranging from 58.27% to 85.16% among corn hybrids, and was higher in flint (75.41%) than in dent types (64.20%). The rapidly digestible starch was higher in dent (72.94%) than in flint (69.57%) corn. On contrary, resistant starch content was higher in flint (8.22%) than in dent (6.03%) corn. The rate of starch digestion for corn kernels could accurately predicted using kernel endosperm characteristics.

Introduction

Although, corn has uniform energetic value, there is growing evidence today that the feeding value of corn samples can vary significantly based on animal performance. There is still no data available to suggest the reasons for these divergences in energetic value (Summers, 2001). However, variability in composition and quality affects the metabolizable energy content with consequential effects on broiler performance (D'Alfonso, 2003). Maize starch provides more than 50% of apparent metabolizable energy (AME_N) of common diets for broiler chicken in Croatia. Moreover, any factor which has an effect on starch digestibility would be expected to influence AME_N in corn based broiler diets.

Corn starch is almost entirely (97-99%) contained in endosperm. Flint corn has hornier and dent corn has flourier endosperm. Rose et al. (2001) found that weight gain and feed conversion ratio increase together with the wheat grain hardness. Weurding (2002) and D'Alfonso (2003) found that the starch of similar total digestibility provides different broiler chickens performances. Weurding et al. (2002) showed that site, rate and extent of starch digestion in small intestine of broiler chickens differ considerably within a wide range of untreated feedstuffs. Broiler chickens grow faster and more efficiently on a diet containing a minimum amount of slowly digestible and resistant starch (Weurding et al., 2002, 2003).There is a lack of information about the relation between the kinetics of corn starch digestion and the type of endosperm.

The objective of this study was to investigate differences *in vitro* kinetics of starch digestion in the small intestine of broiler chicken between horny and floury corn endosperm.

Materials and Methods

This study was performed with twelve corn hybrids (Bc 354, Bc 462, Bc 4982, Bc 566,Bc 5982, OSSK 303, OSSK 444, OSSK 373, Stefania, Florencia, F70, Galice) differing in the proportion of horny and floury endosperm. According to Philippeau and Michalet-Doreau (1998) the (semi)dent corn is characterised by the presence of a horny endosperm at the side and back of the kernel; the central core extends to the crown of the kernel and is floury. (Semi)flint corn has a horny endosperm surrounding a small proportion of the floury endosperm. A kernel of flint corn is rounded with no denting. The mass content of both horny and floury endosperm was determined by manual dissection of the kernel (Correa et al., 2002). *In vitro* starch digestion procedure simulates the consecutive digestion processes in different part of the small intestine of the broiler. Test tubes containing the corn samples,

glass balls, a mixture of digestive enzyme and buffer solution were incubated in a shaking water bath (37^0C) according to Weurding (2001). After nine incubation times (0, 0.25, 0.5, 0.75, 1, 2, 3, 4, 5 and 6 h) the aliquot was taken from the tubes and the amount of released glucose was measured calorimetrically. Starch digestion coefficients were calculated for each incubation time and were used for further estimation of the starch fraction digestibility proportion. Rapidly digestible starch (RDS) represents starch digestion after 2 h incubation whereas slowly digestible starch (SDS) represents digestion after 4 h. Resistant starch (RS) is not digestible in small intestine. Dry matter (105^0C, 16h), crude protein and sugar were determined according AOAC (1990) methods 934.01, 974.06 and 976.05, respectively, Starch using enzymatic method (Englyst et al., 1992). All analysis was performed in duplicate. Differences *in vitro* kinetics of starch digestion between the horny and floury endosperm were tested using the Student t-test (SAS, 1987).

Results and Discussion

The composition of 12 starch corn hybrid types was shown in Table 1. The horny endosperm was ranging from 58.27% to 85.16% among corn hybrids, and was significantly ($P<0.002$) different between flint (75.41%) and dent (64.20%) types, receptively. The crude protein content was similar within endosperm type. On contrary, differences were found between horny and floury in flint (8.91% and 8.36%, respectively) and in dent (6.62% and 6.02%) corn. Floury endosperm had a thinner protein matrix than the horny portion. Consequently the result is lower protein content in floury than in horny portion (Hamilton et al., 1951). The average content of starch for the dent and flint types (74.41% and 74.26%, respectively) and sugar (0.86% and 0.77%, respectively) were similar. The flint and dent corn differed markedly ($P<0.05$) in the content of rapidly digestible starch. In agreement with McAllister et al. (1993) starch is embedded within protein matrix and shielded by cell walls in flint corn and these physical structures may adversely affect starch digestion in the small intestine of broiler chickens. Flint and dent corn endosperm types had similar and uniform level of slow digestible starch. However, flint had more (8.22%) resistant starch compared to dent corn type (6.03%).

Table 1. The influence of endosperm type on corn grain characteristics and in *vitro* kinetics of starch digestion

Item	Flint			Dent				
	Mean	Min	Max	Mean	Min	Max	SEM	P-value
Horny endosperm, %	75.41	70.47	85.16	64.20	58.27	67.98	2.73	0.002
Floury endosperm, %	24.79	14.85	29.54	35.79	35.79	41.73	2.66	0.002
CP in horny endosperm, %	8.91	7.66	10.67	8.36	6.82	9.50	0.64	0.418
CP in floury endosperm %	6.62	5.04	7.43	6.02	4.65	7.07	0.51	0.259
Starch in DM, %	74.26	71.06	85.48	74.41	69.83	87.46	3.55	0.968
Sugar in DM, %	0.77	0.42	1.11	0.86	0.50	1.11	0.14	0.528
Rapidly digestible starch, %	69.57	65.52	72.88	72.94	71.49	75.24	1.32	0.029
Slow digestible starch, %	22.21	21.28	23.51	21.02	18.17	23.43	1.01	0.265
Resistant starch, %	8.22	5.47	11.49	6.03	3.48	8.00	1.19	0.097

The endosperm characteristics effect on the kinetics of in *vitro* corn starch digestion was shown in Table 2. The rate of starch digestion was negatively (r=-0.87) correlated with the horny endosperm and therefore it could be an accurate predictor of starch digestion rate for corn kernels. Philippeau and Mchalet-Doreau (1998) observed a value of 88.5% variation in ruminal starch digestion which was associated with virtuousness. Weurding et al. (2003) showed that birds fed with relatively more slowly and resistant starch consume more feed and grow faster. Grbesa et al.

(2003) found that chickens fed with flint corn hybrids have larger weight at the age of 21 days.

Table 2. Correlation coefficient between corn endosperm types and in *vitro* rate of starch digestion

	Rates of starch digestion		
Variable	Rapidly	Slow	Resistant
Horny endosperm	-0.87**	0.42	0.75**
Floury endosperm	0.78**	-0.39	-0.66*
Starch	0.29	-0.55	0.07

Conclusion

The proportion of horny and floury endosperm varies considerably among examined corn hybrids. The flint had less rapidly digestible fraction of corn starch in the small intestine of chickens than dent corn hybrids. Kernel endosperm characteristics may be a simple and accurate predictor of starch digestion rate for corn kernels.

References

AOAC, (1990) Association of Official Analytical Chemists. Official Methods of Analysis. 15th Edition, Arlington, Virginia, USA.

CORREA, C.E., SHAVER, R.D., PEREIRA, M.N., LAUER, J.G. and KOHNT, K. (2002) Relationship between corn vitreousness and ruminal in situ starch degradability. Journal of Dairy Science 65:3008-3012.

D'ALFONSO, T.H. (2003) Factors affecting ileal digestible energy of corn in poultry diets. Recent Advances in Animal Nutrition 14:151-156.

ENGLYST, H.N., KINGMAN, S.M. and CUMMINGS, J.H. (1992) Classification and measurement of nutritionally important starch fractions. European Journal of Clinical Nutrition 46, (Suppl. 2): S33-S50.

GRBESA, D., KAPS, M., KIS, G., SVECNJAK, Z. and JANJECIC, Z. (2003) Vrednovanje domaćih hibrida kukruza u tovu pilića. Zbornik radova V Simpozij "Peradarski dani 2003" s međunarodnim sudjelovanjem. Poreč, 14-17. svibnja 2003. pp. 69-78.

HAMILTON, T.S., HAMILTON, B.C., JOHNSON C, B. and MITCHELL, H.. (1951) The dependence of the physical and chemical composition of the corn kernel on soil fertility and cropping system. Journal of Cereal Chemistry 15:852-867.

McALLISTER, T.A., PHILLIPE, R.C., RODE, L.M. and CHENG, K.J. (1993) Effects of the protein matrix on digestion of cereal grains by ruminal micro organisms. Journal of Animal Science 71:205-212.

PHILIPPEAU, C. and MICHALET-DOREAU, B. (1998) Influence of genotype and ensiling of corn grain on in situ degradation of starch in the rumen. Journal of Dairy Science 81:2718-2184.

ROSE, S.P., TUCHER, L.A., KETTLEWELL, P.S. and COLLIER, J.D.A. (2001) Rapidly test of wheat starch in broiler chickens. Journal of Cereal Science 34:181-190.

SAS, (1987) SAS/STAT Guide for Personal Computers, Version 6,. SAS Institute Inc. Cary, NC, USA.

SUMMERS, J. D. (2001): Maize: Factors affecting its digestibility and variability in its feeding value. In: Bedford, M.R., Partridge, G.G. (Ed.), Enzymes in Animal Nutrition. CAB International. 109-124.

WEURDING, R.E.,VELDMAN, A., VEEN, W. A. G., VAN DER AAR, P.J. AND VERSTEGEN, M. W. A. (2001). Starch Digestion Rate in the Small Intestine of Broiler Chickens Differs among Feedstuffs. Journal of Nutrition.131:2329-2335

WEURDING, R. E. (2002) Kinetic of starch digestion and performance of broiler chickens. Ph.D.Thesis, Wageningen Institute of Animal Science, Animal Nutrition Group, Wageningen University, The Netherlands, pp 155.

WEURDING, R.E., ENTING, H. and VESTEGEN, M.W.A. (2003) The effect of site of starch digestion on performance of broiler chickens. Animal Feed Science and Technology 110:175-184.