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# THE EFFECT OF MAIZE GRAIN TYPE ON DIGESTIBILITY OF STARCH IN THE RUMEN OF SHEEP

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## A B S T R A C T

Ruminal starch digestibility of dried maize grain and whole plant maize silage was determined by the *in sacco* method. It was found out that starch of dent type maize hybrid is more extensively digested in the rumen than starch of flint type hybrid. Digestibilities of dried maize grain from dent and flint type hybrids were 683 and 554 g $kg^{-1}$ respectively. Ruminal digestibilities of corresponding silages were 915 and 743 g $kg^{-1}$. Ruminal digestibility of starch in whole plant maize silage was on average about 200 g $kg^{-1}$ higher than in dried grain samples. Ruminal starch digestibility of maize silages can not be estimated directly on the basis of measurements done on dried grain samples. Some practical implications of differences among hybrids and between dried and ensiled maize are discussed.

Key words: sheep / animal nutrition / feed / maize / grain / silage / starch / rumen / digestibility

# VPLIV TIPA KORUZNEGA ZRNJA NA PREBAVLJIVOST ŠKROBA V VAMPU OVC

## I Z V L E Č E K

*Z in sacco* metodo smo določili vampno prebavljivost posušenega koruznega zrnja in koruzne silaže iz cele rastline. Ugotovili smo, da je prebava škroba zobanke v vampu intenzivnejša od prebave škroba trdinke. Prebavljivost škroba posušenega zrnja zobanke v vampu je bila 683 g $kg^{-1}$, prebavljivost trdinke pa 554 g $kg^{-1}$. Vampni prebavljivosti ustreznih silaž sta bili 915 in 743 g $kg^{-1}$. Vampna prebavljivost škroba silaže iz cele rastline je bila v povprečju za približno 200 g $kg^{-1}$ večja kot pri posušenem zrnju. Vampne prebavljivosti škroba koruznih silaž ne moremo ocenjevati neposredno na podlagi meritev na vzorcih posušenega zrnja. V razpravi je opisan praktičen pomen medhibridnih razlik in razlik med posušeno in silirano koruzo.

Ključne besede: ovce / prehrana živali / krma / koruza / zrnje / silaža / škrob / vamp / prebavljivost

## INTRODUCTION

Wide variation among different maize hybrids in ruminal dry matter (Verbič *et al*., 1995) and starch (Philippeau and Michalet-Doreau, 1997) digestibility was reported recently. In both

studies variability was attributed to different grain types – dent or flint. It was found out that variation persisted also after the ensiling process (Verbič and Babnik, 1998). Some benefits of lower ruminal starch degradability in flint type hybrids, such as higher digestion of fibrous material and more efficient microbial protein synthesis in the rumen were also reported by the same authors. A comparison between starch degradability of dried grain samples and fresh silage samples is given in this study. The experiment was conducted to see whether degradability of starch was affected by the ensiling process and whether dried grain samples were representative for the estimation of starch degradability in maize silages.

## MATERIAL AND METHODS

### Material

Seeds of two maize hybrids, from which one belonged to dent and the other to flint type, were sown in alternate row design. Fifteen ears of each hybrid were sampled at maturity suitable for silage production and dried at 60 °C. Grains were then separated from cobs, milled through 5 mm screen and used for degradation studies. Whole plant maize silage was also prepared from the same material. Field experiments, harvesting methods and chemical composition of maize grain and corresponding silages have been described in detail by Verbič *et al*. (1997).

### Methods

Animals and feeding

Three adult Solčavska breed sheep, each of them fitted with a rumen cannula, were used. They were given a diet composed solely of maize silage (1170 g DM $day^{-1}$ on average). Diets were supplemented with urea (12.6 g N $kg^{-1}$ DM) as a source of rumen degradable nitrogen and mineral vitamin mix. Animals had free access to water.

Degradation studies

Degradability of starch in the rumen was determined by the *in sacco* method as described by Ørskov *et al*. (1980). About 11 g of fresh silage samples or about 5 g of maize grain were weighed into dacron bags (100×75 mm). Bags with fresh silage samples were stored at –20 °C before degradability measurements. Samples were incubated in the rumen of sheep for 3, 6, 12, 24 and 48 hours. For determination of washing loss (A) the bags with samples were soaked in hot water (39 °C) for 1 hour instead of incubating them in the rumen. After incubation the bags with samples were washed first under tap water and then in a domestic washing machine. In the case of silage samples all measurements were done separately on two diets, i.e. in the rumen of sheep which were given silage made from dent and flint type hybrid. Bags in triplicates were incubated in three sheep in two time repetitions. Each value for a certain incubation time is therefore a mean of 36 measurements (3 bags × 3 sheep × 2 time repetitions × 2 diets). The maize grain samples were incubated in the rumen of the same three sheep which were given a mixture of dent and flint type hybrid silage in a ratio of 1:1. One bag per sheep in one time series was used (3 bags per sample at certain incubation time). It was found out that the type of diet did not affect degradability of starch from maize silage and therefore we believe that the results for silage and dried maize grain are comparable despite slight modifications in diets used during the experiment.

Calculations

Degradabilities of starch at single incubation times (DS) were expressed as a proportion of starch which disappeared from the bags during the incubation in the rumen. The calculated degradabilities were fitted to the equation $DS = a + b \times (1 - e^{-c \times t})$ as described by Ørskov and McDonald (1979). For silage samples where initial lag time ($t_0$) appeared, McDonald´s (1981) model was used. Lag time was calculated as $t_0 = \frac{1}{c} \times \ln \frac{b}{a+b-A}$. Effective starch degradabilities (ESD) in silages were calculated as $ESD = A + \frac{b \times c}{c+k} \times e^{-(c+k) \times t_0}$ (McDonald, 1981). For the calculation of ESD in grain the equation $ESD = a + \frac{b \times c}{c+k} \times \left(1 - e^{-(c+k) \times t_{1000}}\right)$ (Ørskov and McDonald, 1979) was used. The parameter $t_{1000}$ represents time when the curve $DS = a + b \times (1 - e^{-c \times t})$ reaches the value 1000 g $kg^{-1}$. A theoretical outflow rate $k = 0.05$ $h^{-1}$ was adopted in calculations of ESD.

Chemical analyses

Starch in samples of maize grain, silages and undigested residues from the dacron bags were determined by the enzyme method recommended by Boehringer (1995).

## RESULTS AND DISCUSSION

### Degradation of starch in the rumen – dent *vs.* flint type grain maize

The extent of starch degradation in dent type hybrid was considerably higher than in flint (Graph 1 and Table 1). It happened in both - dried grain and ensiled whole plant samples. In silages the difference among hybrids was the consequence of difference in fraction which disappeared from nylon bags instantly (A, 763 *vs*. 509 g $kg^{-1}$) as well as the consequence of different degradation rates (c, 0.107 *vs*. 0.075 $h^{-1}$). In dried grain samples the difference was due exclusively to the difference in degradation rate (Graph 1). Variation among hybrids in ESD of dried grain was similar as reported for grain collected at similar whole plant dry matter concentration by Philippeau and Michalet-Doreau (1997). According to our knowledge, there are no data in the literature on degradability of fresh silage samples. The difference in ESD between dried dent and flint silage samples, as reported by Philippeau and Michalet-Doreau (1998), was lower (116 g $kg^{-1}$) than the difference found in fresh silage samples from the present experiment (172 g $kg^{-1}$). It seems that the difference between flint and dent type hybrid slightly increases during the ensiling. In dried grain samples it was 129 g $kg^{-1}$ while in silages it was 172 g $kg^{-1}$. The value for ESD of dent type silage (915 g $kg^{-1}$) is very close to the *in vivo* result reported by Galyean (1976) (893 g $kg^{-1}$).

### Degradation of starch in the rumen – dried maize grain *vs.* ensiled whole plant maize

There was a large difference in the course and extent of starch degradation among dried and ensiled samples. As almost 98 % of starch in whole maize silage appeared in grain fraction (Verbič *et al*., 1997) we believed that the results were comparable despite the fact that dried grain and fresh whole plant silage samples were used in present study. Starch fraction which disappeared from dacron bags without being incubated in the rumen (A) was markedly higher in silage samples than in dried grain (Table 1, Graph 1). In silages ESD was on average for 210 g $kg^{-1}$ higher than in dried grain samples. The difference was considerably higher than reported by

Philippeau and Michalet-Doreau (1998), who found out that degradability of starch increased by about 60 g $kg^{-1}$ due to ensiling process. Disagreements can be due to differences in methodology. All samples used by French authors were dried at 40 °C, while we used fresh silage samples and grain samples that were dried at 60 °C.

Table 1. Characteristics of ruminal starch digestion in grain and whole plant silages from dent and flint type hybrids

Preglednica 1. Značilnosti prebavljanja škroba zrnja in silaž iz cele rastline zobanke in trdinke v vampu

| | Maize silage – Koruzna silaža | | Maize grain – koruzno zrnje* | |
|---|---|---|---|---|
| | Dent type – Zobanka | Flint type – Trdinka | Dent type – Zobanka | Flint type – Trdinka |
| Degradability of starch in the rumen (DS) (g $kg^{-1}$) | | | | |
| Prebavljivost škroba v vampu (DS) (g $kg^{-1}$) | | | | |
| 3 h | 793 | 548 | 300 | 230 |
| 6 h | 828 | 542 | 458 | 313 |
| 12 h | 923 | 675 | 657 | 471 |
| 24 h | 977 | 873 | 952 | 747 |
| 48 h | 990 | 945 | - | 989 |
| Parameters of degradation curves of starch in the rumen and effective starch degradability | | | | |
| Parametri krivulj prebavljanja škroba v vampu in dejanska prebavljivost v vampu | | | | |
| A (g $kg^{-1}$) | 763 | 509 | 137 | 136 |
| a (g $kg^{-1}$) | 706 | 289 | 139 | 126 |
| b (g $kg^{-1}$) | 290 | 682 | 1132 | 1088 |
| c ($h^{-1}$) | 0.107 | 0.075 | 0.053 | 0.033 |
| SE (g $kg^{-1}$) | 12 | 25 | 12 | 17 |
| $t_0$ (h) | 2.0 | 5.2 | - | - |
| $t_{1000}$ (h) | - | - | 27.3 | 48.6 |
| ESD (g $kg^{-1}$) | 915 | 743 | 683 | 554 |

* - In the calculation of degradation curves of dried grain samples it was not possible to limit the potential starch degradability (a+b) by the value 1000 g $kg^{-1}$ as usually done in such calculations

* - Pri računanju krivulj prebavljanja vzorcev posušenega zrnja ni bilo mogoče omejiti potencialne prebavljivosti škroba v vampu (a+b) z vrednostjo 1000 g $kg^{-1}$, kot je običajno pri podobnih izračunih

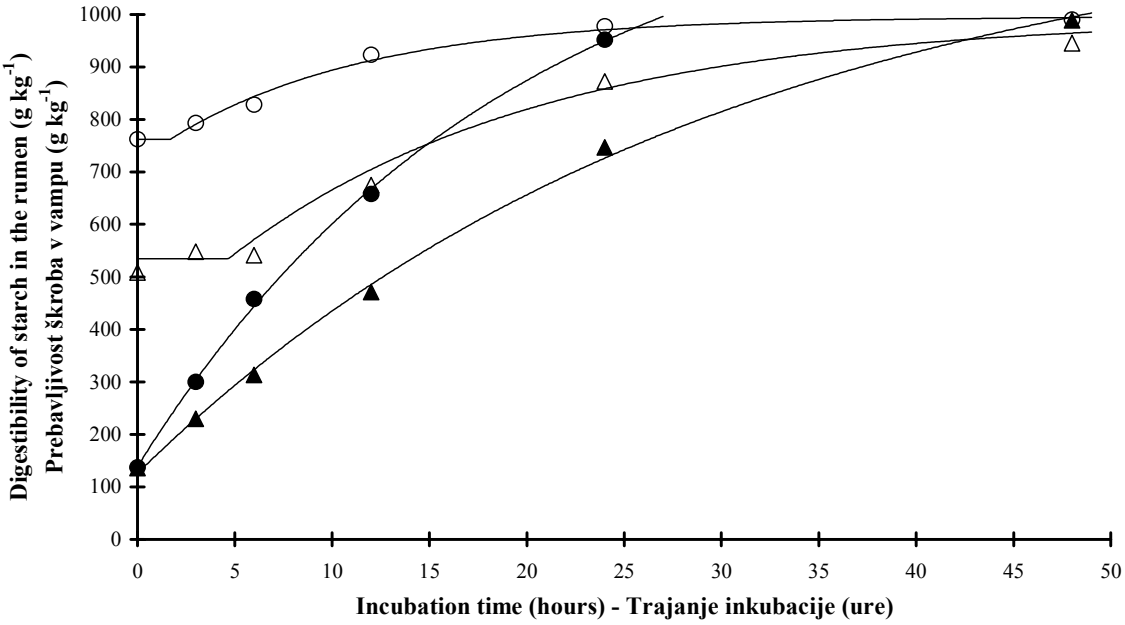
LEGEND: A – starch fraction which was washed out from the dacron bags without incubating them in the rumen; a, b, c - coefficients from the equation $DS = a + b(1-e^{-ct})$, coefficient c representing degradation rate; SE – standard error of estimate of the equation $DS = a + b(1-e^{-ct})$; $t_0$ - lag time; $t_{1000}$ – time at which estimated DS = 1000 g $kg^{-1}$; ESD - effective starch degradability calculated using a rumen outflow rate k=0.05 $h^{-1}$

LEGENDA: A – frakcija škroba, ki se je sprala iz dakronskih vrečk brez inkubacije v vampu; a, b, c – koeficienti iz enačbe $DS = a + b(1-e^{-ct})$, koeficient c predstavlja stopnjo prebavljanja; SE – standardna napaka ocene enačbe $DS = a + b(1-e^{-ct})$; $t_0$ – čas do pričetka prebavljanja v vampu; $t_{1000}$ – čas, pri katerem je ocenjen DS = 1000 g $kg^{-1}$; ESD – dejanska prebavljivost škroba v vampu, izračunana ob upoštevanju stopnje iztoka iz vampa k=0,05 $h^{-1}$

## Possible practical implications

Ruminants can benefit from the shift of starch digestion from the rumen to small intestine because of decreased methane loss from the rumen and improved efficiency of metabolizable energy usage (Gädeken *et al*., 1995). However, all the benefits of rumen undegradable starch can be lost when the amount of starch that passes to small intestine exceeds its capacity for digestion. There are several factors, such as low pancreatic α-amylase concentration (Huntington, 1997), low intestinal disaccharidase activity (Kreikmeier and Harmon, 1995) and limited absorptive capacity for glucose (Krehbiel *et al*., 1996), that may be limiting to small intestinal starch digestion. The optimal starch digestion in the rumen therefore depends largely on the amount of

starch in the diet as well as on the specific nutrient requirements of animals. Flachowsky (1994) calculated that optimal starch degradability in dairy cows receiving 5 kg of starch per day would be about 80 % while in cows receiving 2.5 kg of starch per day the optimal value would be even lower (65 %). On the basis of the results from the Table 1 it can be speculated that flint hybrids are more suitable for silage production (ESD ≈ 75 %) and dent hybrids for grain production (ESD ≈ 70 %). However, it does not mean that flint type hybrid grain with extremely low starch degradability (≈ 55 %) can not be efficiently used, especially in diets containing highly degradable barley starch.




Graph 1. Degradation curves of grain (closed symbols) and whole plant silages starch (opened symbols) from dent (○,●) and flint (△,▲) type maize hybrids

Grafikon 1. Krivulje prebavljanja škroba zrnja (polni simboli) in silaže iz cele rastline (prazni simboli) zobank (○,●) in trdink (△,▲) v vampu

## CONCLUSIONS

It can be concluded that starch of dent type hybrid maize is more extensively degraded in the rumen than starch of flint type hybrid. Degradability of starch in whole plant maize silage was about 200 g $kg^{-1}$ higher than in dried grain samples. Starch degradability of maize silage can not be estimated directly on the basis of measurements done on dried grain samples.

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