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Influence of maize grain drying process on its in situ degradability in dairy cows

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ABSTRACT

Rumen degradability of fresh (61% DM – end of wax-ripe stage), freeze dried, and oven dried (at 40°C for 5 d and 60°C for 1 and 3 d) maize grain was determined by in situ incubation for 0, 2, 4, 8, 12, 16, 24 and 48 h with four nonlactating Holstein-Friesian cows. Oven dried material was degraded at a lower level compared to fresh and freeze dried material. The degradability values of organic matter, starch and crude protein of fresh and freeze dried grains differed significantly from oven dried grains until an incubation time of 12 h ($P<0.01$). Correlation coefficients between organic matter and starch degradability, organic matter and crude protein degradability and starch and crude protein degradability were 0.99, 0.97 and 0.97, respectively. In the early hours of incubation the fresh material showed a higher degradability (washing losses up to 19 percentage points) compared to the freeze dried material. Above 8 h of incubation the freeze dried material showed slightly higher degradability values. Effective degradability decreased with increasing temperature, especially at high outflow rates.

It can be concluded that it is essential to pay attention to sample preparation, which has to be described for comparing results from different degradability studies. Besides, the results show that oven drying increases the bypass of starch.

KEY WORDS: dairy cow, degradability, maize grain, drying process

INTRODUCTION

The importance of *in situ* methods to determine the extent and dynamic of rumen degradability has been growing, hence standardizing the incubation technique to obtain reproducible and comparable results in different laboratories has

also attracted attention in recent years. The different factors influencing the degradability of nutrients have to be taken into account. The influence of sample size, number and structure was demonstrated by Lindberg (1981), whereas that of the basal ration by Mould and Ørskov (1983) and Thompson and Moran (1986). A review of influencing factors was recently given by Vanzant et al. (1998). As demonstrated by Vik-Mo (1989), preparation of samples is a crucial point if comparable degradability values are to be obtained.

The objective of this investigation was to study the effect of different drying procedures on the *in situ* degradability of maize grain.

MATERIAL AND METHODS

The study was carried out with 4 nonlactating Holstein-Friesian cows (average liveweight 650 kg) fitted with large rumen cannulas, kept in a tie stall and fed twice a day (06.30 and 14.30 h). The basal ration consisted of 7.5 kg grass silage dry matter (DM) and 150 g minerals per day. Water was given *ad libitum*.

Rumen fluid was withdrawn once throughout the trial to control normality of ruminal processess. The ammonia concentration was determined by a modified Conway method (Voigt and Steger, 1967). The rumen fermentation criteria varied within normal ranges (pH: 6.38-6.75, ammonia concentration: 16.7-28.4 mg NH_3-N/100 ml rumen fluid).

Maize grain on the cob was either freeze dried or oven dried at 40°C for 5 d or 60°C for 1 or 3 d. Fresh and dried grain was ground using a 3 mm sieve. The differently prepared samples (4 g) were then placed in 10 x 20 cm, 53 µm pore size nylon bags, 2 replicates in each of the 4 cows. Rumen incubations started at the morning feeding and lasted for 2, 4, 8, 12, 16, 24 and 48 h. After incubation, the bags were rinsed under cold running tap water and washed twice using a standard washing machine program. The bags were dried at 60°C for 24 h, weighed, emptied and pooled according to incubation time for further analysis. To determine the washing loss (0 h) 5 replicates were rinsed in the washing machine without incubation and then treated like the other samples.

In fresh, dried and incubated material the DM content was determined by oven drying at 105°C to a constant weight, crude ash by oven drying at 550°C, crude protein according to Dumas (Aulrich and Gollum, 1997), and starch according to Salomonsson et al. (1984). Calculations were performed to establish the degradability of organic matter, crude protein and starch and the effective degradability of organic matter and starch for different outflow rates (Ørskov and McDonald, 1979).

The statistical analysis was carried out according to Flak (1994). Due to sample pooling it was only possible to determine the effect of incubation time and drying process but not the effect of the animals.

RESULTS

The chemical composition of the grass silage is given in Table 1.

Strong positive correlations were found between the degradability values of some nutrients. The correlation coefficients between organic matter and starch, organic matter and crude protein, and starch and crude protein were r = 0.99, r = 0.97 and r = 0.97, respectively. Differences within the variants of oven drying for organic matter, starch and crude protein were not significant. The effects of the drying process, incubation time, and their interaction were significant at each incubation time (P<0.01).

TABLE 1

Chemical composition of grass silage (GS) and maize grain (MG) before drying, g/kg DM

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N – free extractives	Starch
GS	391.0	876.0	138.9	20.8	352.5	363.8	–
MG	611.0	985.2	102.9	56.9	24.0	801.4	75.4

Organic matter

The differences between the degradability values of fresh and oven dried grain at 0, 2, 4, 8, 12, 16, 24 and 48 h of incubation were 33.4, 30.6, 26.7, 20.7, 15.1, 10.8, 3.7, and 0.2 percentage points (pp), respectively. These differences were statistically significant up to 12 h incubation time (P<0.01). The differences between freeze dried and oven dried maize grain at the above incubation intervals were of 15.0, 17.8, 18.4, 21.3, 16.4, 12.2, 5.7, and 1.0 pp, respectively, which were significant up to 12 h of incubation.

When fresh grain was compared with freeze dried grain, the fresh material showed higher degradability values in the early hours of incubation [at 0, 2 and 4 h 18.4 (P<0.01), 12.8 (P<0.05) and 8.3 pp, respectively]. Above 8 h the freeze dried material showed a slightly higher degradability (0.6-2.1 pp; Figure 1).

Starch

The degradability values of starch are similar to those of organic matter (Figure 2).

The differences between the degradability values of fresh and oven dried grain at 0, 2, 4, 8, 12, 16, 24 and 48 h of incubation were 34.9, 21.1, 27.9, 21.1, 15.5, 9.6, 4.7, and 0.2 pp, respectively. These differences were statistically significant up to 12 h incubation time (P<0.01). The following differences were found between the degradability values of freeze dried and oven dried grain: 15.9, 18.1, 18.8, 20.7,

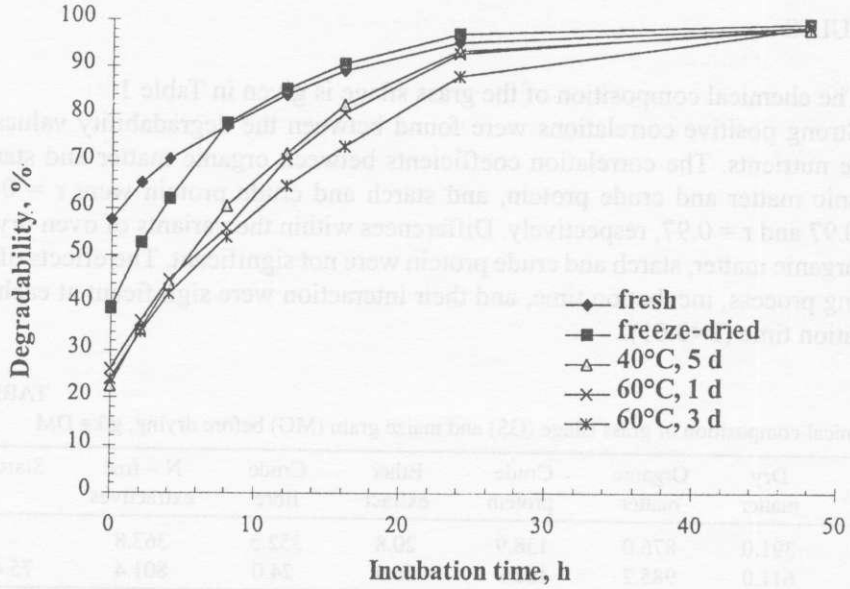

Figure 1. Organic matter degradability *in situ* of variously dried maize grain depending on incubation time, %

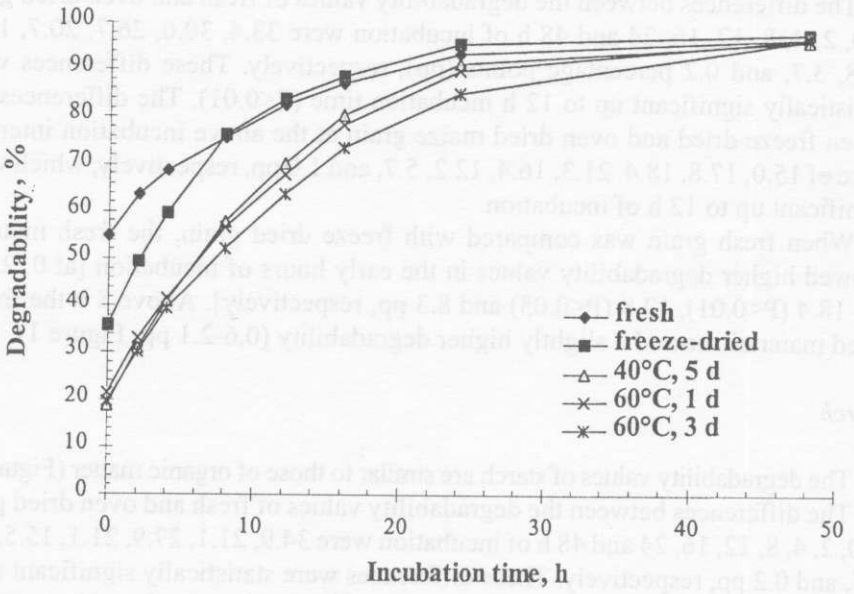

Figure 2. Starch degradability *in situ* of variously dried maize grain depending on incubation time, %

16.5, 11.3, 6.8, and 1.0 pp, respectively. The differences were again significant up to 12 h of incubation.

Similar to organic matter, the fresh material showed higher degradability in the early hours of incubation [at 0, 2 and 4 h incubation time 19.0 ($P<0.01$), 14.1 ($P<0.05$) and 9.0 pp, respectively]. Above 8 h the freeze dried material showed slightly increased degradability values (0.6-1.7 pp).

Protein

Due to insufficient sample material for 48 h, protein analysis was performed only up to 24 h of incubation.

Differences between fresh and oven dried material detected at 0, 2, 4, 8, 12, 16 and 24 h were 27.4, 26.1, 23.5, 15.8, 14.6, 11.6, and 8.5 pp, respectively, between freeze dried and oven dried material 16.1, 18.4, 19.7, 17.5, 16.1, 14.6, and 11.7 pp, respectively. These differences were highly significant up to 4 h of incubation ($P<0.01$) and moderately significant up to 12 h ($P<0.05$; Figure 3).

In relation to organic matter and starch, the fresh compared to freeze dried grain showed a higher degradability in the first hours (at 0, 2 and 4 h incubation time 11.3, 7.7 and 3.8pp). Above 8 h of incubation the freeze dried material had a slightly higher degradability.

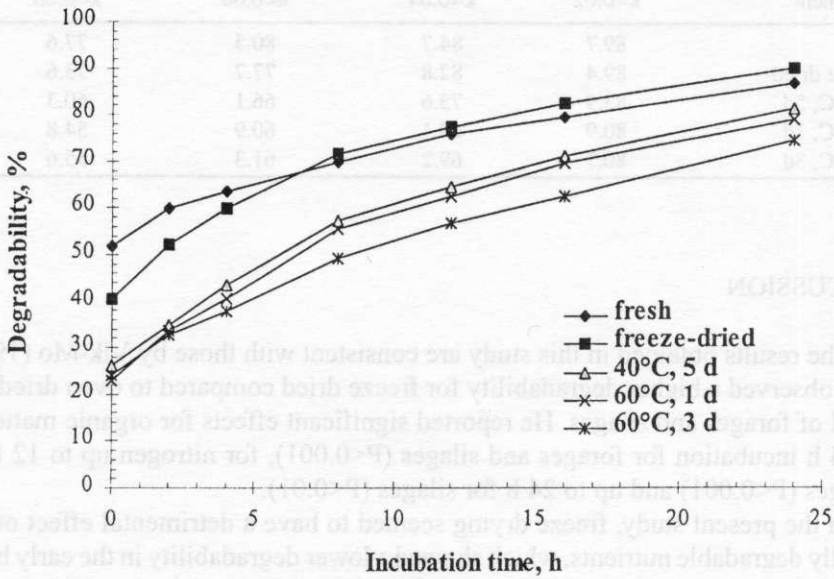

Figure 3. Crude protein degradability *in situ* of variously dried maize grain depending on incubation time, %

Effective degradability of organic matter and starch

The effective degradability was calculated using the degradation model modified by Ørskov and McDonald (1979) for different outflow rates for organic matter and starch (Tables 2 and 3). For organic matter as well as starch, it can be pointed out that with increasing temperature, effective degradability decreased. This was particularly conspicuous at high outflow rates.

TABLE 2

Effective degradability of organic matter (%) at different outflow rates (k)

Treatment	k=0.02	k=0.04	k=0.06	k=0.08
Fresh	91.4	86.2	82.4	79.5
Freeze dried	91.2	84.8	79.8	75.8
40°C, 5d	85.1	75.1	67.8	62.2
60°C, 1d	81.1	69.4	61.4	55.5
60°C, 3d	80.8	69.5	61.9	56.4

TABLE 3

Effective degradability of starch (%) at different outflow rates (k)

Treatment	k=0.02	k=0.04	k=0.06	k=0.08
Fresh	89.7	84.7	80.5	77.6
Freeze dried	89.4	82.8	77.7	73.6
40°C, 5d	83.9	73.6	66.1	60.3
60°C, 1d	80.9	69.1	60.9	54.8
60°C, 3d	80.7	69.2	61.3	55.6

DISCUSSION

The results obtained in this study are consistent with those by Vik-Mo (1989), who observed a higher degradability for freeze dried compared to oven dried material of forages and silages. He reported significant effects for organic matter up to 24 h incubation for forages and silages ($P<0.001$), for nitrogen up to 12 h for forages ($P<0.001$) and up to 24 h for silages ($P<0.01$).

In the present study, freeze drying seemed to have a detrimental effect on the rapidly degradable nutrients, which showed a lower degradability in the early hours of incubation. The degradability above 8 h of incubation of the insoluble, potentially degradable nutrients was increased by freeze drying, probably due to slight

damage of the granule surface. Because rumen microorganisms penetrate the starch granules using their proteolytic and amylolytic activities, and digest the inside of the starch granules (McAllister et al., 1989), thus damaged, but not denaturated granules, create good conditions for digestion.

The oven drying probably resulted in browning and denaturation reactions (Vik-Mo, 1989), which yielded components that may retard digestion. Goelema et al. (1997) refer to the formation of highly degradable complexes within the granule or between starch and proteins as well as to decreased digestion of the rapidly degradable fraction, which resulted in this study in differences up to 30 percent points in this fraction. Associations and complexes between starch granules and protein matrix in the endosperm alter the accessibility of starch granules to ruminal bacteria (Philippeau et al., 1997).

The drying treatment of feedstuffs can be of interest in decreasing rumen degradability and increasing bypass nutrients. Drying above 60°C in vaccum, however, can result in popping reactions (Turner et al., 1995) and, thus, increase rumen degradability.

CONCLUSIONS

Analysis of the obtained results pertaining to degradability shows that it is essential to pay attention to sample preparation, which has to be described in order to compare results from different degradability studies. Freeze-drying decreases degradability values only in the early hours of incubation, whereas oven drying decreases degradability permanently by up to 30 percent points, probably due to browning and denaturation reactions. Beside this, the results showed that oven drying increased bypass-starch.

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STRESZCZENIE

Wpływ procesu suszenia ziarna kukurydzy na jego rozkład *in situ* u krów mlecznych

Rozkład w żwaczu świeżego (61% s.m.) ziarna kukurydzy, zebranego w stadium woskowej dojrzałości, liofilizowanego lub suszonego przy 40°C przez 3 dni lub w 60°C w ciągu 1 do 3 dni oznaczano metodą *in situ* na 4 zasuszonych krowach z przetokami do żwacza.

Ziarno suszone było rozkładane w żwaczu w mniejszym stopniu w porównaniu ze świeżym i liofilizowanym. Współczynniki degradacji po 12 godzinach inkubacji substancji organicznej, skrobi i białka ogólnego świeżego i liofilizowanego ziarna różniły się istotnie ($P<0,01$) od wartości dla ziarna suszonego. Współczynniki korelacji między rozkładem substancji organicznej i skrobi, substancji organicznej i białka ogólnego oraz skrobi i białka ogólnego wynosiły 0,99; 0,97 i 0,097, odpowiednio. W pierwszych godzinach inkubacji rozkład składników pokarmowych świeżego ziarna był szybszy niż liofilizowanego (straty płukania do 19 jednostek procentowych); powyżej 8 godz. inkubacji otrzymano nieco większą wartość dla ziarna liofilizowanego. Wartości efektywnego rozkładu obniżały się przy zwiększającej się temperaturze, szczególnie przy wysokim tempie przepływu.