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Influence of distillers dried grains with solubles (Starprot) in dairy cow feeding

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ABSTRACT

The objective of this study was to investigate the suitability of distillers dried grains with solubles (DDGS) from two grain species (wheat, corn) as a protein supplement for the feeding of dairy cows. The feedstuffs produced by an Austrian distillery were incubated in the rumen of four fistulated steers. Values for the effective degradability (ED) of dry matter (DM) at assumed ruminal passage rates of 2, 5, and 8 % h^{-1} averaged 73.1, 62.0 and 56.1 % respectively. The mean potential degradability ($a + b$) of DM was 88.3 % and the mean degradation rate of the DDGS was 4.75 % h^{-1}. Based on an in vivo digestibility trial with wethers energy contents (NEL) of 6.93 MJ kg^{-1} DM for DDGS from wheat and 8.18 MJ kg^{-1} DM for DDGS of corn were calculated. A feeding trial using 15 lactating dairy cows showed neither significant differences in dry matter intake (DMI) nor in milk yield and composition between the DDGS treatments and the control diet, which contained a mixture of rapeseed cake and soybean meal as protein supplement. The mean DM intake in all groups was 20.9 kg d^{-1} with a milk yield of 26.2 kg d^{-1} and concentrations of 4.46 % fat and 3.35 % protein in the milk. Due to the slow degradability of the DDGS and therefore high values for undegraded dietary protein (UDP) as well as the similar milk production results we conclude that the DDGS used in this study can be considered as alternative protein sources to the traditional supply with soybean meal.

Keywords: dairy cattle, nutrition, protein supplement, DDGS, degradability, digestibility, milk yield

1 INTRODUCTION

As there are numerous grain processing distilleries in the United States of America by-products from alcohol fermentation like distillers dried grains (DDG) or distillers dried grains with solubles (DDGS) accumulate and most research regarding this type of feedstuff originates from the USA. In Europe there is a noticeable trend towards renewable energy sources. Thus in the near future there will be a rise in the production of liquid biofuels such as bioethanol. The utilization of the by-products will be of major interest for this industry using grains as resource so that an estimated amount of 170.000 t DDG/DDGS (AGES, 2005) will enter the Austrian agricultural market as animal feedstuff. The use of DDG and DDGS in the nutrition of animals, especially cattle, has been investigated widely (Palmquist and Conrad, 1982; Voss et al., 1988; Broderick et al., 1990; McGuffey et al., 1990; Owen and Larson, 1991; Grings et al., 1992; Armentano, 1994; Powers et al., 1995; Nichols et al., 1998; Liu et al., 2000; Al-Suwaiegh et al., 2002; Kleinschmidt et al., 2005) but there are few European studies about distillers dried grains (Dunkel, 2005; Preißinger, 2005). To check the suitability of DDGS produced by an Austrian distillery (*Starprot*) for dairy cow feeding and obtain further information for the assessment of these increasingly interesting feedstuffs for farmers a feeding trial with lactating dairy cows was carried out accompanied by an in vivo digestibility trial with wethers and in situ investigations with rumen fistulated steers. The main objective of the study was to test the influence of distillers dried grains with solubles (from wheat and from corn) as a protein supplement on the lactation performance compared to a control group fed with a soybean meal and rapeseed cake mixture.

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2 MATERIALS AND METHODS

The study was conducted at the Federal Agricultural Research and Education Centre (HBLFA) Raumberg-Gumpenstein, Austria.

2.1 In situ procedure

The in situ investigations on ruminal dry matter degradation were conducted according to the specifications of Ørskov et al. (1980), Michalet-Doreau et al. (1987), Madsen and Hvelplund (1994), Huntington and Givens (1995) and the NRC (2001). For the incubation of the feedstuffs four steers averaging 1130 kg body mass equipped with rumen fistulas were used. The incubation times were 0, 2, 4, 8, 12, 20, 32, 48, 72 and 96 h. As the experimental concentrates (soybean meal, rapeseed cake, DDGS from wheat, DDGS from corn) were expected to have slow degradation rates, the last two incubation times should serve as an appropriate estimation of the asymptote of the degradation curve (Mertens, 1993). The data obtained was fitted to the exponential model of Ørskov and McDonald (1979):

$$\text{DEG} = a + b\,(1 - e^{-ct})$$

where DEG is the degradability of DM at time t, a stands for the immediately soluble fraction at initiation of the incubation (time 0), b represents the proportion of DM potentially degradable in the rumen, c is the degradation rate of fraction b and t the time of incubation. As the degradability is considerably influenced by the rumen outflow rate, the effective degradability (ED) of DM at assumed rates of passage k = 0.02, 0.05 and 0.08 h^{-1} was calculated as follows (Ørskov and McDonald, 1979):

$$\text{ED} = a + \frac{b}{k + c}$$

where a, b, and c are the same parameters as described earlier. Further details are given in Gruber et al. (2005).

2.2 In vivo digestibility trial

To derive the energy value of DDGS from wheat and DDGS from corn an in vivo digestibility trial was conducted according to the guidelines of the Society of Nutrition Physiology (GfE, 1991). For the investigations four wethers were kept in metabolic cages and fed diets with increasing rates (0, 25, 50 and 75 %) of concentrates. Based on the individual digestibility data at these levels a linear regression of digestibility on concentrate proportion was made to extrapolate for the digestibility coefficients (Figure 1).

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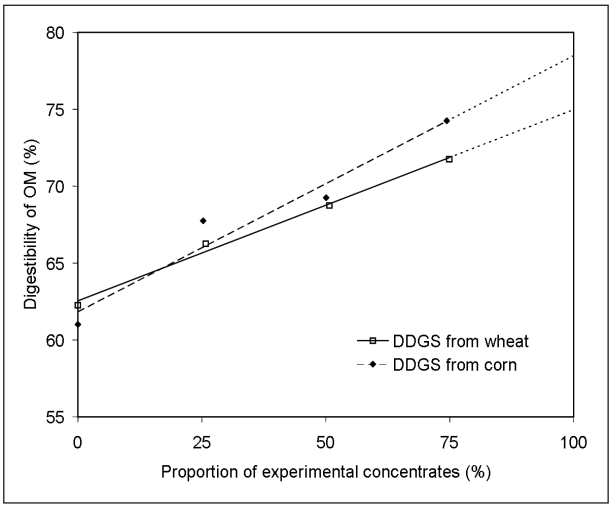

Fig. 1: Regression method for the calculation of the digestibility of nutrients (e.g. OM)

Based on the digestibility coefficients the energy content (ME, NEL) of the two DDGS was calculated using the equations given by the GfE (2001).

2.3 Feeding trial

Cows, diets and experimental design

The feeding trial was carried out based on a replicated Latin square design (2 trials (T1, T2) × 3 treatments × 3 periods), with each period lasting four weeks. In T1 9 cows were used (7 Holstein, 1 Brown Swiss, 1 Simmental), in T2 there were 6 cows (4 Holstein, 1 Brown Swiss, 1 Simmental). The average milk yield at the start of the trial was 24.5 kg d^{-1} in T1 and 34.1 kg d^{-1} in T2.

The forage diet consisted of 50 % grass silage (second cut), 30 % corn silage and 20 % hay (first cut) on a DM basis and was offered ad libitum targeting 5 to 7 % refusals. Starting from 14 kg possible milk from forage the cows received 0.5 kg concentrate (fresh matter) for every kg milk yield beyond. The cows received 100 g of mineral feed and 40 g of stock salt daily. The concentrates consisted of energy components (barley, wheat bran) and protein components varying according to the treatments. The control diet (C) contained a mixture of rapeseed cake, soybean meal and vegetable fat. The diets representing the issue of this study contained DDGS from wheat and fat (DDGS-W) as well as DDGS from corn (DDGS-C). The rapeseed cake and the fat were used to adjust for balanced nutrients. The formulation of the treatment concentrates is shown in Table 1. The concentrates were aimed to be equal in the content of NEL, crude fat and nXP (nutzbares Rohprotein, utilizable crude protein at duodenum; GfE, 2001).

Table 1: Ingredient composition of experimental diets

	Control	DDGS-W	DDGS-C
Ingredient (% fresh mass)			
Barley	72.0	74.3	74.7
Wheat bran	8.0	8.3	8.3
Rapeseed cake	12.0	-	-
Soybean meal	7.0	-	-
DDGS from wheat	-	15.8	-
DDGS from corn	-	-	17.0
Vegetable fat	1.0	1.8	-

Measurements and chemical analysis

Milk production was recorded at each milking. Milk compositional analysis was made with individual samples also taken at each milking and pooled for one day. They were analyzed for fat, protein, lactose, SCC and milk urea. Live weights were recorded weekly and BCS every second week. After the first 21 d, which were for adaptation, individual feed intakes and refusals were determined in the last 7 d of each experimental period. Composite samples of grass silage, corn silage, hay and the concentrate mixtures taken in each period were analyzed for DM and Weende crude nutrients according to the guidelines of ALVA (1983). The composite samples were also analyzed for the Van Soest cell wall constituents NDF, ADF and lignin (Van Soest, 1994), for minerals and trace elements as well as for the organic matter solubility in cellulase (ELOS) following the method described by VDLUFA (1993). Based on the resulting ELOS values the energy content of the forages (grass silage, corn silage, hay) was calculated according to the equations of the GfE (1998; 2001).

Statistical analysis

Data from the feeding trial was analyzed using model 3 of LSMLMW PC-1 (Harvey, 1987) with the fixed effects "treatment", "period", "trial" and the random effect "cow within trial".

3 RESULTS AND DISCUSSION

3.1 In situ degradability of dry matter

The results of the in situ investigations are shown in Table 2.

As the degradability of feedstuffs is influenced by processing or rather conservation, the DDGS from wheat and from corn were expected to have slow rates of degradation because of the drying. Therefore large proportions of rumen undegradable protein would be available, which especially are needed to meet the requirements of high-yielding dairy cows.

The DM degradation rates of the distillers dried grains with solubles (4.7 % h^{-1} for DDGS from wheat, 4.8 % h^{-1} for DDGS of corn) are lower than of soybean meal (6.8 % h^{-1}). DDGS also show lower potential degradation

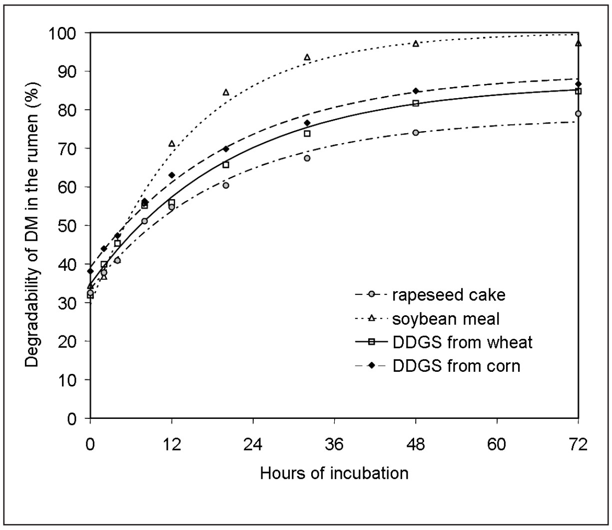

Fig. 2: Degradability of DM of protein concentrates (Gruber et al., 2005)

Table 2: In situ dry matter degradation parameters (Gruber et al., 2005)

	a	b	c	(a + b)	ED2	ED5	ED8
Rapeseed cake	33.3	44.7	0.053	78.0	65.2	55.8	50.7
Soybean meal	29.4	67.9	0.068	97.3	81.8	68.5	60.5
DDGS from wheat	34.8	52.1	0.047	86.9	71.4	60.1	54.1
DDGS from corn	39.1	50.5	0.048	89.6	74.7	63.8	58.0

a = immediately soluble fraction (%),
b = potentially degradable fraction (%),
c = degradation rate of the b fraction (h^{-1}),
(a + b) = potential degradability (%),
ED = effective degradability (%) at an assumed rates of passage of 0.02, 0.05, 0.08 h^{-1}

values of DM in the rumen ($a + b$) (86.9 % and 89.6 % for DDGS from wheat and corn, respectively) than soybean meal (97.3 %). Thus these protein concentrates on the one hand provide a higher proportion of undegraded nutrients (e.g. CP) to the small intestine, but release nutrients in smaller amounts as well as in slower rates for the supply of the rumen microbes. This is mainly due to the drying at the end of the production process. Figure 2 illustrates these findings showing the fitted degradation curves of the DM up to three days after incubation.

The results of the in situ experiment are consistent with a study of Batajoo and Shaver (1998), who report a DM degradability for DDG of 84.2 % and a degradation rate of 4.9 % h^{-1}. Other published values (Boila and Ingalls, 1994; Woods et al., 2003) for the potential degradability are also in the same range but with much lower rates of degradation (about 3.4 % h^{-1}) and consequently lower effective degradabilities. A possible reason for these differences could be both a longer drying of the distillers grains or higher drying temperatures, moreover it is unclear if the by-products used in studies mentioned contained solubles or not. Due to the fact that higher-yielding dairy cows have an increased dry matter intake, the rumen outflow rates are elevated. The results of the effective degradability calculations show that the advantages of DDGS over soybean meal drop slightly the more the passage rate rises (Table 2). At $k = 0.02$ h^{-1} (ED2) there is a wider difference (nearly 9 % on the average) between the ED values than at an assumed k of 0.08 h^{-1} averaging about 5 % difference.

As the evaluation of the in situ protein degradation of the DDGS is still pending an estimation of the amount of undegraded dietary protein (UDP) based on this approach is not possible yet. But due to the chemical fractionation results (Table 3) according to the Cornell Net Carbohydrate and Protein System (CNCPS) (Sniffen et al., 1992) high values can be expected.

Table 3: Protein fractions (CNCPS) of the protein concentrates (% of CP) (Gruber et al., 2005)

	A	B1	B2	B3	C
Rapeseed cake	18.6	0.6	51.2	11.0	18.5
Soybean meal	9.8	2.7	79.5	5.0	3.0
DDGS from wheat	11.8	0.3	59.6	20.2	8.0
DDGS from corn	8.3	0.2	69.5	13.7	8.3

The relatively high proportions of the B_2 and B_3 fractions in the DDGS confirm that drying reduces the protein degradation rate in feedstuffs (Van Soest, 1982) and this is in accordance with the in situ DM degradation parameters obtained for these concentrates. Reported UDP levels for distillers dried grains range from 45 % (Powers et al., 1995; DLG, 1997) up to 60 % (Grings et al., 1992; Batajoo and Shaver, 1998).

3.2 In vivo digestibility of nutrients

Table 4 shows the results of the digestibility trial.

Table 4: Digestibility in vivo of nutrients and calculated energy content of the DDGS

	Digestibility coefficients (%)					Energy content (MJ kg^{-1} DM)	
	OM	CP	EE	CF	NFE	ME	NEL
DDGS from wheat	75.0	77.7	53.4	47.3	79.6	11.48	6.93
	± 0.9	± 1.4	± 4.0	± 2.4	± 1.1		
DDGS from corn	78.5	84.0	85.1	42.6	80.4	13.34	8.18
	± 1.7	± 1.7	± 3.1	± 4.0	± 2.8		

„OM = organic matter, CP = crude protein, EE = ether extract, CF = crude fibre, NFE = nitrogen free extracts „ ME = metabolizable energy, NEL = net energy lactation

The digestibility of organic matter is higher in DDGS from corn (78.5 %) than DDGS from wheat (75.0 %). These coefficients are in agreement with tabular values from Sauvant et al. (2004) but not necessarily with Lodge et al. (1997), who calculated a dOM of 71.6 % for DDGS from corn. The energy contents of DDGS from wheat and corn differ comparatively strongly (6.9 MJ kg^{-1} DM and 8.2 MJ kg^{-1} DM, respectively). One of the reasons is the high concentration of crude fat in DDGS from corn (up to 13 % of DM). Therefore it is important to distinguish between these feedstuffs when talking about dairy cow feeding with DDGS as a protein supplement and always to specify the grain species. Currently published energy contents of DDGS from corn range between 7.75 and 8.25 MJ NEL kg^{-1} DM, for DDGS from wheat there is a value of 7.49 MJ NEL kg^{-1} DM (DLG, 1997; NRC, 2001; Sauvant et al., 2004).

In Europe the assessment of the nutritive value of distillers dried grains with solubles is still under way. Factors of the ethanol production process such as selection of grains (type and quality), milling process, type and efficiency of fermentation, drying temperature and duration as well as the amount of solubles blended back into the wet product at the time of drying, cause variability in DDGS properties (Belyea et al., 1989, 1998, 2004; Spiehs et al., 2002). This must be considered when evaluation is in the final stages.

3.3 Feeding trial

Table 5 shows the average chemical composition as well as the energy content of the diet ingredients. The energy content of the two DDGS was calculated based on the digestibility coefficients of the in vivo trial and using regression equations for GE, ME and NEL of GfE (2001). The energy content of the forages was estimated by regression equations considering ELOS and crude nutrients (GfE, 1998) whereas the energy content of the control concentrate was calculated according to digestibility values of the tabulated components as given in DLG (1997). As intended the content of crude fat, nXP and NEL was very similar in the three experimental concentrates. However, protein content and degradability naturally were different.

The results of the feeding trial are listed in Table 6. The dry matter intake (DMI) averaged 20.9 kg and the milk yield 26.2 kg d^{-1}. There were no significant differences in the treatments regarding these parameters. As there were no differences in energy intake of the cows this resulted in similar body masses (656 kg). Milk composition was also nearly identical ($P > 0.05$), averaging 4.46 % fat and 3.35 % protein. Significant differences between groups were observed for the crude protein intake and concentration ($P < 0.05$ and $P = 0.001$, respectively), which were higher for cows fed the C diet (3317 g, 159 g kg^{-1} DM) compared to DDGS-W (3264 g, 156 g kg^{-1} DM) or DDGS-C (3197 g, 154 g kg^{-1} DM). This is evident as the same trend is noticeable in the CP contents of the experimental feedstuffs and the DMI was similar. As expected there were also highly

Table 5: Nutrient composition of experimental feedstuffs

	Forages			Concentrates		
	Hay	„Grass silage“	„Corn silage“	Control	DDGS-W	DDGS-C
DM (g kg^{-1} FM)	831	413	315	872	870	870
Nutrients (g kg^{-1} DM)						
Crude protein	149	173	89	194	186	177
Crude fat	22	34	34	40	40	41
Crude fibre	275	270	224	80	69	69
N-free extracts	468	418	606	646	669	678
Ash	86	106	47	40	37	35
NDF	519	477	452	286	296	297
ADF	311	318	253	93	84	77
ADL	34	34	30	27	24	17
nXP	135	135	127	185	191	190
UDP (% of CP)	20.7	15.0	25.0	28.2	37.3	39.7
RNB	+ 2.2	+ 6.0	- 6.1	+ 1.4	- 0.8	- 2.1
Energy content (MJ kg^{-1} DM)						
ME	9.81	9.96	10.14	12.90	12.72	12.75
NEL	5.83	5.90	6.03	8.07	7.94	7.97
Minerals (g kg^{-1} DM)						
Ca	5.8	6.3	2.7	1.9	1.7	1.6
P	3.3	3.3	2.2	6.7	6.0	6.1
Mg	2.1	2.5	1.4	1.8	1.5	1.5
K	21.6	27.3	13.1	9.6	9.4	9.5
Na	0.29	0.29	0.08	0.17	0.54	0.58
Trace elements (mg kg^{-1} DM)						
Mn	95	84	27	31	40	26
Zn	30	28	20	34	37	34
Cu	9.7	10.9	6.8	7.0	8.6	7.0

significant (P < 0.001) differences in the UDP values and the ruminal nitrogen balance (RNB). The DDGS-C treatment showed best results in this regard (25 % UDP of CP and 0.43 g RNB kg^{-1} DM). The control group had the lowest UDP proportion (22 % of CP) and the worst RNB (1.56 g kg^{-1} DM) value, DDGS-W lay in between (24 % UDP of CP, 0.91 g RNB kg^{-1} DM). These differences among treatments can also be explained by the chemical composition of the concentrates used.

The constant DMI in this experiment is in accordance with other studies using distillers dried grains in dairy cow rations (Palmquist and Conrad, 1982; Owen and Larson, 1991; Grings et al., 1992; Powers et al., 1995; Kleinschmidt, 2005; Dunkel, 2005). Previous results regarding the milk yield are controversial. Van Horn et al. (1985) explain weaker lactation performances with a heat-damaging of DDGS in the drying procedure. Dunkel (2005) also gives intelligible reasons for the lower

Table 6: Results of the feeding trial

	Treatment1			RSD	P
	Control	DDGS-W	DDGS-C		
DMI (kg d-1)					
Hay	2.73	2.83	2.76	0.38	0.785
Grass silage	7.43	7.64	7.39	0.46	0.311
Corn silage	4.20	4.30	4.25	0.35	0.771
Forage	14.36	14.76	14.40	0.89	0.421
Concentrates	6.44	6.09	6.38	0.99	0.605
Total DMI2	20.87	20.92	20.84	0.60	0.941
Nutrient intake (g)					
Crude protein	3317	3264	3197	110	0.026
nXP	3118	3153	3150	118	0.672
RNB	31.8	17.7	7.5	11.3	< 0.001
NEL (MJ)	137.2	136.0	136.3	4.9	0.800
Nutrient concentration (g kg-1 DM)					
Crude protein	159	156	154	3	0.001
Crude fat	34	34	34	1	0.742
Crude fibre	202	202	199	8	0.511
N-free extracts	531	533	540	13	0.177
NDF	414	421	419	13	0.419
ADF	234	235	230	10	0.333
ADL	31	30	28	1	< 0.001
nXP	149	150	151	2	0.201
UDP (% of CP)	21.7	24.5	25.5	0.9	< 0.001
RNB	+ 1.56	+ 0.91	+ 0.43	0.54	< 0.001
ME (MJ kg-1 DM)	10.84	10.74	10.79	0.12	0.087
NEL (MJ kg-1 DM)	6.56	6.48	6.53	0.09	0.102
Milk production and composition					
Milk yield (kg d-1)	26.16	25.91	26.40	1.71	0.751
Fat (%)	4.43	4.48	4.46	0.24	0.862
Protein (%)	3.39	3.34	3.33	0.13	0.420
Lactose (%)	4.71	4.67	4.69	0.13	0.631
Body mass (kg)	660	652	660	15	0.074
BCS	2.69	2.67	2.68	0.17	0.647

[1]Control included rapeseed cake, soybean meal and vegetable fat; DDGS-W = distillers dried grains from wheat plus vegetable fat; DDGS-C = distillers dried grains from corn; [2]including minerals

milk production of the control group in her investigations (lower energy intake due to differences in the energy content of treatment diets, different performances at the beginning of the trial). Voss et al. (1988), Nichols et al. (1998) and Liu et al. (2000) do not report on any differences in milk yield whilst Owen and Larson (1991) and Kleinschmidt et al. (2005) recorded better performances for cows fed diets containing DDGS in their studies. In consideration of these inconsistent results it is not possible to draw a general conclusion about the influence of DDGS on milk yield. In our feeding trial there were neither differences in the milk fat concentration nor milk protein concentration. This corresponds to findings of Nichols et al. (1998), Liu et al. (2000) and Dunkel (2005). Although distillers grains can provide high levels of (unsaturated) fat and thus have an impact on rumen function, current dataset (14 reviewed studies (adapted from Santos et al., 1998; extended) on the usage of distillers dried grains (with solubles) in dairy cow rations plus this investigation) does not support the common theory (in the USA) that feeding DG results in milk fat depression. Lower milk protein percentages were evident in older studies. Lower lysine concentrations, caused by worse processing and drying procedures (lysine is very heat-sensitive) of the distillers grains and an unbalanced amino acid profile might have contributed to this effect. The quality of protein in DDGS can be good, still a scarceness in lysine can lead to decreased milk protein percentage in diets hbased primarily on corn products.

4 CONCLUSIONS

The in situ results of our investigations suggest high amounts of rumen undegradable protein in DDGS due to relatively low potential degradability and slow degradation rate of the dry matter. The CNCPS protein fractioning supports this assumption. The digestibility trial has led to energy contents of DDGS which approximately correspond with the few existing tabular values. As the nutrient contents of DDGS from wheat and corn differ, the grain species from which the foodstuff origins should always be considered when talking of DDGS. In the feeding trial neither differences in dry matter intake nor in milk yield and composition between the control and the DDGS treatments could be observed.

In conclusion distillers dried grains with solubles can be considered as an alternative protein source to the traditional supply with soybean meal. However, care must be taken when balancing diets for high-yielding dairy cows. Further investigations have to focus on possible variability in composition and nutritive value of DDGS from different production sites as the availability of this concentrate will increase. In addition more research is needed to determine up to which inclusion levels distillers dried grains can be used in corn-based dairy cow diets because their amino acid profile will never reach the same quality as that of soybean meal.

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