

EFFECTS OF CORN DISTILLERS DRIED GRAINS AND CORN GLUTEN IN THE DIET OF DAIRY COWS: A COMPARATIVE ANALYSIS OF THEIR IMPACT ON MILK YIELD

Dominika Friessová, Alena Pechová, Lenka Kudělková,
Petr Doležal, Leoš Pavlata

*Department of Animal Nutrition and Forage Production, Faculty of
AgriSciences, Mendel University in Brno, Zemedelska 1, Czech Republic*

Corresponding email address: xfriesso@mendelu.cz

ABSTRACT

The experiment compared the effect of wet distillers' grains with solubles (WDGS) and enriched corn gluten (CG) on the milk production and milk composition of 86 Holstein dairy cows. The experiment group received 4 kg of WDGS per cow in their daily total mixed ration (TMR), while the control group received 4 kg of CG per cow. The results demonstrated that the CG group achieved a significantly higher milk yield at week 7 of the trial (April) compared to the WDGS group (40.63 kg vs. 37.21 kg, $p \leq 0.01$). In contrast, the WDGS group showed a significantly higher milk protein content from week 3 to week 11 of the trial ($p \leq 0.01$) and higher fat content at week 11 (4.21 vs. 3.96%; $p \leq 0.05$). Higher levels of milk urea were also observed in the WDGS group ($p \leq 0.01$) during multiple sampling periods. Both by-products proved to be effective subsites for concentrate mixtures. While CG promoted a higher milk volume, WDGS improve milk quality parameters (protein and fat concentrations). However, the use of WDGS requires more precise balancing of nitrogenous fractions and energy in the rumen due to its higher acidogenity and nutritional variability.

Keywords: nutrition; daily ration; Holstein cattle; milk parameters; milk urea; bioethanol by-products, fatty acids

INTRODUCTION

The production of bioethanol from crops, mostly corn and wheat, has undergone significant technological advancements over the past decades, leading to the large-scale production of nutritionally valuable bioproducts (Malik et al. 2024; Garnsworthy et al. 2021). In the Czech Republic, this development was accelerated



by legislative changes after 2008, which introduced mandatory biofuel additive requirements. Modern distilleries produce corn distillation by-products as distillers' grains with solubles (DGS) in dried (DDGS) or wet (WDGS) form. This is significantly different from water-based, low-nutrient feeds produced in the past.

Current DDGS represent a highly concentrated source of crude protein (more than 300 g/kg dry matter), with roughly 50% of these nitrogenous substances consisting of rumen-undegradable protein (RUP), which is crucial for high-producing dairy cows in the early stage of lactation. Despite the high protein content, a low concentration of essential amino acid lysine remains a limiting factor in corn by-products (Kalscheur 2005; Kudrna et al. 2011). Alongside DGS, corn gluten feed (CGF) is an important by-product of the wet-milling process. It is valued for its high digestibility of its neutral detergent fiber (NDF) and its potential to partially replace energy-dense cereals (Ertl et al. 2015; St-Pierre & Weiss 2015).

Research by Mammi et al. (2022) suggests that incorporating distillery by-products into the feed ration can increase milk production. However, high doses of WDGS carry the risk of increased diet acidogenicity and potential development of subacute ruminal acidosis. Considering that feed costs often represent more than 50–60% of total milk production costs, the use of agricultural by-products could be an economic necessity. Although the properties of WDGS are well documented, comparative studies evaluating the effects of WDGS versus enriched corn gluten on milk production are limited.

This experiment aims to conduct a comparative analysis of the effects of incorporating WDGS into the diet of Holstein dairy cows, compared with the corn gluten diet, on milk production.

MATERIAL AND METHODS

Animals and experimental groups

The experiment was conducted on a commercial herd of Holstein dairy cows. The experiment involved four production sections of dairy cows, which were divided into two treatments, with two sections serving as the experimental group and another two as the control group. From the base population of both treatments, a total of 86 cows were selected using the principle of analogical pairs, with 43 cows from the experimental group and 43 cows from the control group. The cows were selected based on three key parameters: lactation number, days in milk (DIM) and milk yield prior to the start of the experiment (Table 1). The experiment lasted for 16 weeks.

Tab. 1: Dairy cows from experimental ($n = 43$) and control ($n = 43$) groups before the start of the experiment

N	Lactation number	Days in milk	Milk yield (kg)
WDGS group	2.44 ± 1.26	92.56 ± 41.35	39.05 ± 6.81
CG group	2.44 ± 1.26	93.0 ± 39.47	39.01 ± 5.52

n – number of cases, WDGS – wet distillers' grains with solubles, CG – corn gluten

Sample collection

Data on milk yield and milk composition were obtained from the official milk recording scheme conducted by the Czech-Moravian Breeders' Corporation (ČMSCH). The monitored parameters included milk yield, concentration of milk components (fat, protein, lactose), urea, citric acid, ketone bodies (acetone and beta-hydroxybutyrate), and free fatty acids. Samples of WDGS were collected weekly for laboratory nutritional analysis.

Experimental diets

The diet was presented as a total mixed ration (TMR). The experimental group received WDGS at a rate of 4 kg per cow per day on a fresh matter basis. The control group received the same amount (4 kg/cow/day) of enriched corn gluten (CG), a feed supplement consisting of corn gluten, soluble fractions from molasses, and fiber, with an average dry matter (DM) content of 64 %. The diet rations were formulated to ensure that nutrient concentration differed minimally between the two group. The calculated compositions of the rations are shown in Table 2. Due to the introduction of a new alfalfa silage for the final three weeks of the experiment, the ration components were recalculated to maintain a stable nutrient concentration through the entire study.

Tab. 2: Nutritional composition of the ration during the experiment

	Date	March	CG	13. May	CG
	units	WDGS		WDGS	
NEL	MJ/kg DM	6.39	6.29	6.20	6.08
NL	g/kg DM	161.02	159.22	155.66	154.9
NDF	g/kg DM	322.87	320.48	344.99	346.00
ADF	g/kg DM	195.45	201.28	201.89	212.12
Starch	g/kg DM	238.1	226.51	251.21	231.42
NSC	g/kg DM	404.32	390.64	397.12	377.61
DM	kg	27.93	27.98	28.14	28.80

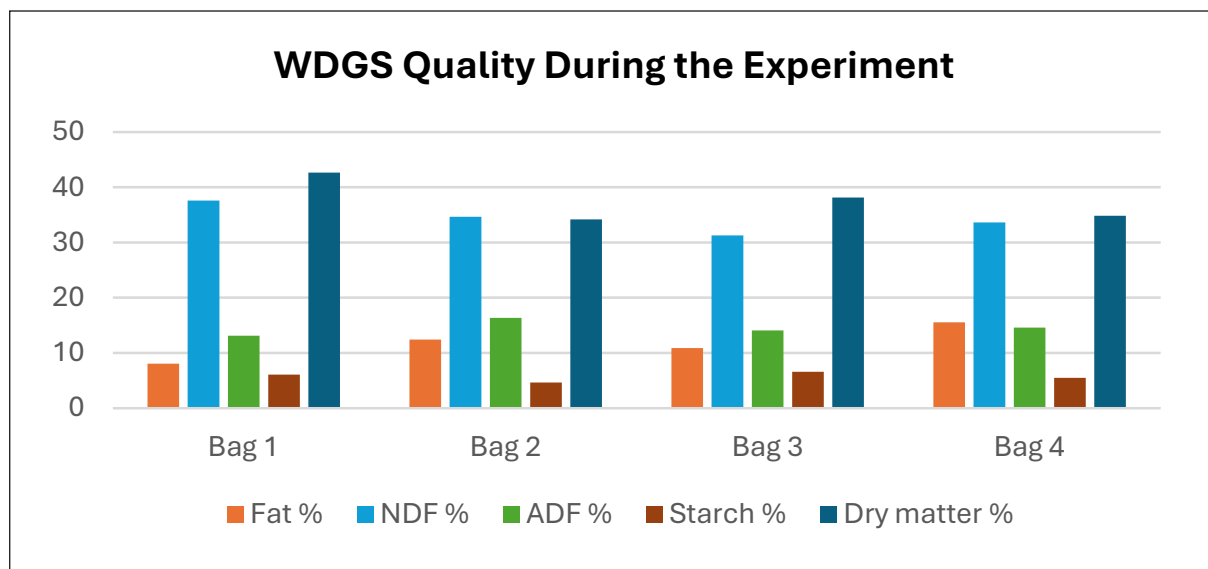
CG – Corn gluten, WDGS – Wet distiller's grains with solubles, NEL – Net Energy for Lactation, NL – Net Energy for Lactation, NDF – Neutral Detergent Fiber, ADF – Acid Detergent Fiber, Starch – Starch, NSC – Non-Structural Carbohydrates, DM – Dry Matter

Statistical analysis

Data were statistically analysed using MS Excel. Mean differences between the two feeding groups were evaluated using an unpaired Student's t-test after verifying the equality of variances with a F-test. Statistical significance was declared at $p \leq 0.05$. Additionally, a one-way analysis of variance (ANOVA) was performed to evaluate differences in nutrient composition among the four separate batches (bags) of WDGS used. When significant differences were detected, post hoc comparison were performed using Tukey's honestly significant difference (HSD) test at significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

We determined that the nutritional composition of the WDGS varied considerably throughout the experiments (Graf 1).



Graf 1: WDGS Quality During the Experiment

Averages of samples taken from a same bag: Bag 1 (13.2. – 12.3); Bag 2 (13.3 – 1.4.), Bag 3 (2.4 – 30.4.); Bag 4 (1.5 – 28.5)

The crude fat content showed quite high variability, ranging from 8% to 16%, with significant differences between individual storage bags; the highest values were found in bag 4 and the lowest in bag 1. Similarly, substantial variability was found in NDF content (31–38%), which was significantly higher in bag 1 compared to the others. In contrast, the percentage of ADF did not show significant differences and its concentration in individual bags ranged from 13 to 16%. Starch content varied from 4.6% to 6.6%. These fluctuations in fat and starch contents indicate that the net energy density differ between individual batches of WDGS. The last evaluated parameter was dry matter content which is crucial for the aerobic stability of wet by-products during storage. Dry matter ranges from 34% to 43% with bag 1 having the highest values, followed by bag 3, while bags 2 and 4 had lower values. These differences in the composition of the WDGS during the experiment could influenced the results, because for high producing dairy cows is important stability of the nutritional composition of the ration. Our findings reflect the natural variability of distillery co-products, where composition varies depending on the production process or aerobic deterioration during storage.

The effect of the dietary treatments on milk production parameters is summarised in Table 3. The results showed that cows fed the corn gluten (CG) had a significantly higher milk yield after week 7 of the trial (40.63 kg vs. 37.21 kg; $p \leq 0.05$). In the other months, the differences were smaller and did not reach statistical significance, though the CG diet maintained a numerically higher trend. Buenavista et al. (2021) and Benchaar et al. (2013) stated that co-products such

as WDGS can partially replace corn grain and protein sources such as soybean meal, without negatively affecting milk production if their inclusion is in the range of 20–30 % of dietary DM. The higher milk production observed in the CG group could be attributed to higher stability of the nutrient content in the ration. The next factor might be differences in fiber digestibility. Corn gluten is valued for its high NDF digestibility, serving as an effective energy substitute for corn grain while also promoting rumen stability (Wickersham et al. 2004; Magalhães Wanderley et al. 2025). The higher milk yield in the CG group may thus relate to the dietary characteristics of corn gluten, whose fermentable fiber helps maintain an optimal pH in the rumen, reduces the risk of subacute ruminal acidosis, and supports total tract organic matter digestibility. This statement is supported by Magalhães Wanderley et al. (2025). By contrast, the diet containing WDGS was more acidogenic, particularly due to the final nutrient balancing of the diet. Mammi et al. (2022) also stated that the addition of WDGS can result in a more acidogenic diet. The WDGS diet was richer in both starch and non-structural carbohydrates (NSC). WDGS used in our experiment contain 4–6 % of starch and in TMR was the total starch also slightly higher (Table 2).

Throughout the experimental period, the WDGS group consistently had a higher milk protein percentage compared to the CG group, with statistically significant differences from the 3 up to the 11 weeks (Table 3). This outcome aligns with Magalhães Wanderley et al. (2025), who reported that partial as well as complete replacement of conventional concentrate increased the milk protein concentration. As shown in Table 2, the WDGS diet maintained a slightly higher crude protein level (161.02 a 155.66 g/kg DM) compared to CG (159.22 and 154.90 g/kg). Although the difference in NL can be explained by the varying content and quality of protein in the two feeds. Literature data indicate that WDGS or DDGS contain 55–65 % of rumen undegradable protein (RUP or by-pass protein) of total crude protein. Compared to this, corn gluten feed contains a bypass protein of only approximately 20–22 %, with the rest being rumen-degradable protein (Darabighane et al. 2020). Therefore, the higher milk protein content in the WDGS group was likely driven by an increased supply of bypass protein absorbed directly in the small intestine and is not dependent on microbial synthesis of protein in the rumen. The specific amino acid profile of this protein, which avoids rumen degradation, is key to formulating feed rations (Maskaľová et al. 2014).

The WDGS group also reached a significantly higher milk fat content in May (4.21 % vs 3.96 %; $p \leq 0.05$), with a similar numerical trend observed during the other sampling period. Milk fat content is primarily influenced by acetate production from ruminal fiber fermentation and the fat content of the diet itself. Although WDGS are generally considered more acidogenic than CG, they did not exert a negative effect on milk fat percentage in this study. We hypothesize that the higher milk fat concentration was supported by the higher fat content within the WDGS itself. According to our analysis, the fat content of the WDGS ranged between 8 % and 16 %. Consequently, the WDGS diet group had a higher NEL

(6.39 and 6.20 MJ/kg DM) than the CG diet (6.29 and 6.08 MJ/kg) (Table 2). This is consistent with the scientific literature stating that distillers' grains (DGS) often have an energy value 10–15% higher than corn gluten meal, due to their higher fat content (Moureau et al. 2010).

Milk ketone levels (acetone and BHB) remained low and well within the physiological range for both groups. These low concentrations confirms that neither diet induced a negative energy balance. Although significant differences in BHB occurred in April and May, no clear trend was established, and the absolute differences were minimal.

Milk urea levels were significantly higher in the WDGS group in March, April, and June (Table 3). Higher concentration of urea is typically result from a lack of insufficient amounts of available saccharides, poor synchronisation between protein degradation and available energy for microbial growth, or an excessive supply of degradable protein. The concentration of crude protein in our diets was around 15% (which complies with the standard recommendations), the WDGS diet was slightly higher in crude protein than the CG diet. Nevertheless, because WDGS have higher by-pass protein than corn gluten, this pronounced increase in milk urea was unexpected and warrants further investigation into ruminal nitrogen efficiency.

To perform a comprehensive evaluation, raw milk yields were converted to fat-corrected milk (FCM) and energy-corrected milk (ECM). As shown in Table 4, no statistically significant differences were observed for FCM and ECM, despite slightly higher numerical values in the CG group. These quite small not statistically significant differences confirm that both feed by-products provide highly comparable production efficiencies. The choice between them should therefore be guided by individual farm objectives (e.g. milk volume vs. enhancing milk component concentration).

Tab. 3: Milk yield and milk composition in group fed wet corn distillers' grains (WDGS, n = 43) and corn gluten (CG, n = 43) during the experiment

Sampling Date (since start of feeding)	4. March		3. April		6. May		3. June	
	CG		CG		CG		CG	
Groups	WDGS	CG	WDGS	CG	WDGS	CG	WDGS	CG
Milk Yield (kg)	38.50±6,05	39.97±6.10	37.21±5.94**	40.63±5.91**	34.67±5.96	35.94±5.43	33.38±6.56	34.59±5.00
Milk Fat (%)	4.18±0,54	4.02±0.44	4.16±0.51	4.00±0.86	4.21±0.48*	3.96±0.49*	3.95±0.65	3.87±0.54
Milk Protein (%)	3.31±0,24*	3.20±0.25*	3.39±0.21*	3.27±0.23*	3.43±0.25**	3.23±0.25**	3.41±0.23	3.38±0.21
Fat/Protein Ratio	1.26±0,16	1.26±0.16	1.23±0.13	1.23±0.28	1.23±0.11	1.23±0.16	1.16±0.17	1.15±0.16
Milk Lactose (%)	4.95±0,09	4.93±0.09	4.98±0.09	4.99±0.08	4.97±0.10	4.96±0.09	4.90±0.10	4.87±0.09
Urea (mg/100 ml)	28.18±4.87**	23.56±6.29**	31.24±3.33*	29.70±3.78*	31.60±3.66	30.96±3.53	31.33±2.84**	27.99±3.81**
Citric Acid (%)	0.15±0.03**	0.17±0.03**	0.13±0.03**	0.17±0.04**	0.14±0.03	0.13±0.02	0.13±0.03**	0.17±0.05**
Acetone (mmol/l)	0.06±0.03	0.04±0.04	0.05±0.03*	0.03±0.03*	0.03±0.03	0.04±0.03	0.06±0.04	0.06±0.06
BHB (mmol/l)	0.04±0.03	0.04±0.03	0.05±0.03**	0.02±0.02**	0.05±0.03**	0.08±0.03**	0.07±0.03	0.06±0.06
FFA (mmol/100 g fat)	0.96±0.66	1.19±0.86	0.89±0.28	0.95±0.35	1.00±0.38*	1.19±0.39**	1.09±0.45	1.12±0.32

WDGS – Wet distiller's grains with solubles, CG – Corn Gluten, BHB – beta-hydroxybutyrate, FFA – Free Fatty Acids, * statistically significant difference between groups ($p \leq 0,05$), ** statistically significant difference between groups ($p \leq 0,01$)

Tab. 4: Fat corrected milk (FCM) and energy corrected milk (ECM) in group fed wet corn distillers' grains (WDGS, $n = 43$) and group fed corn gluten (CG, $n = 43$) during the experiment

	n	FCM	t-test	ECM	t-test
		3,50 %	p-value		p-value
4. March	WDGS	42.65±7.13	0.6742	42.48±6.60	0.7079
3 weeks	CG	43.29±6.94		43.02±6.63	
3. April	WDGS	41.05±6.25	0.0685	41.12±5.99	0.0591
7 weeks	CG	43.83±7.67		43.80±6.95	
6. May	WDGS	38.49±6.19	0.9970	38.63±6.05	0.8665
11 weeks	CG	38.50±5.78		38.42±5.54	
3. June	WDGS	34.78±8.55	0.2638	35.16±8.51	0.2519
16 weeks	CG	36.52±5.51		36.91±5.23	

FCM – Fat corrected milk for 3.5 % of fat, $FCM = (0.4324 \times \text{kg milk yield}) + (16.216 \times \text{kg milk fat})$ Western et al. (2020).

ECM – Energy-Corrected Milk, $ECM = (0.327 \times \text{kg mléka}) + (12.95 \times \text{kg mléčného tuku}) + (7.20 \times \text{kg mléčného proteinu})$ Western et al. (2020).

CONCLUSION

This experiment confirmed that both wet distillers' grains with solubles (WDGS) and enriched corn gluten (CG) serve as highly effective partial replacements for concentrate mixtures in the diets of high-producing dairy cows. The corn gluten (CG) diet supported a significantly higher raw milk yield at week 7 of the trial and numerically was found similar trend also in other samplings. Conversely, wet distillers' grains with solubles (WDGS) proved to be a tool for enhancing milk component quality, resulting in significantly higher milk protein percentages from week 3 to week 11 and an increased milk fat content in week 7.

However, because no statistically significant differences were detected in standardized milk production parameters (FCM and ECM), both by-products demonstrate comparable overall production efficiency. The choice between utilizing WDGS or CG should therefore be determined by specific farm management priorities, whether the primary goal is to maximize total volumetric milk yield (CG) or to enhance the concentration of milk fat and protein components (WDGS). Furthermore, the inherent nutritional variability of wet distillery by-products observed across different batches underscores the necessity of regular laboratory monitoring to prevent diet instability.

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