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Original article

The impact of using Dried Distillers Grains with Solubles (DDGS) as a substitute for concentrate feeds during the dry period on the quality of bovine colostrum and the IgG levels in their calves' serum

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Abstract

The aim of the study was to determine the changes in the composition and physicochemical properties of cow's colostrum and the levels of immunoglobulin G in the serum of their calves, depending on the inclusion of dried distiller's grains with solubles (DDGS) as a substitute for concentrate feeds in the diet during the dry period. Sixty cows were divided into four groups: Group C – traditional TMR feed, Group I – modified feed with the inclusion of DDGS at 10% of dry matter, Group II – DDGS inclusion increased to 15% of dry matter, Group III – DDGS inclusion increased to 20% of dry matter. Colostrum samples were collected from all cows during the first full milking after calving. Blood samples were taken from all cows after calving and from their calves on days 3rd and 30th of life. No significant changes were observed in the basic composition of cows' colostrum. The levels of amino acids were significantly lower in DDGS groups. There was an increase in a concentrations of IgG, IgM, IgA, lactoferrin, K, Na, and proportion of α-casein and κ-casein in the colostrum of cows receiving DDGS. The total serum protein content was lower in cows receiving DDGS, despite a higher content of IgG. On the 3rd day of life, significantly higher levels of total protein and IgG were found in the calves' serum. Based on the results optained, it can be concluded that the use of DDGS in a cow's diet during the dry period as a substitute for concentrated feeds does not reduce the colostrum quality. However, including DDGS at a level of 15% DM in the cows' diet results in higher IgG content and, consequently, a higher level of passive immunity in their calves.

Keywords: cows, dry off period, Dried Distillers Grains with Solubles, colostrum, calves, IgG

Introduction

Dried Distillers Grains with Solubles (DDGS) is a byproduct of ethanol production used for biofuel or consumption purposes. It can be produced from any grain used in ethanol production (Kennedy et al. 2019). However, corn is the grain most used to produce DDGS. From one ton of corn grain, about 400 liters of ethanol can be obtained, which, with a yield of 8 tons per hectare, allows to produce over 3,000 liters of biofuel. This amount is equivalent to approximately 2,000 liters of gasoline (Naylor et al. 2007, Zachwieja et al. 2022). The composition of DDGS corresponds to the content of the grain components from which the alcohol is produced (Belyea et al. 2010). Due to its high protein, fiber, and energy content, corn DDGS can be successfully used as feed for cattle (Westreicher-Kristen et al. 2014, Fonseca et al. 2021). The primary source of protein in the diet of livestock is typically soybean meal (a byproduct of soybean oil production), rapeseed meal, or rapeseed. However, these feeds are expensive due to climate change, rising fuel, and fertilizer costs (Fatehi et al. 2022). Increasing the use of local byproducts in the diets of dairy cows, especially when replacing imported soybean meal and grains, will also help reduce the carbon footprint of the sourced raw materials (Garnsworthy et al. 2021). DDGS is an excellent source of sulfur (Morris et al. 2018). The high level of this anion helps lower the dietary cation-anion difference (DCAD), which is desirable during the dry period. The DCAD level in the diet during the dry period influences calcium metabolism in cows, reducing the risk of clinical hypocalcemia, which affects milk production and the health of dairy cows (Clark et al. 2024). Therefore, DDGS can be successfully used as feed for dry cows, positively impacting their health status by minimizing the risk of metabolic disorders (Santos et al. 2009). Replacing soybean meal with DDGS in cow's diet results in an increase in rumen undegradable protein (RUP) content (Chesini et al. 2023, Dias et al. 2024). According to other authors, this feeding method leads to a linear reduction in rumen ammonia concentration and a decrease in nitrogen excretion through urine, thereby contributing to the reduction of nitrogen waste pollution in livestock production (Dias et al. 2024). DDGS, as a source of RUP, improves feed intake without affecting dry matter digestibility, milk protein content, or milk yield in cows (Chesini et al. 2023). Therefore, DDGS can be a valuable substitute for concentrate feeds in cow's nutrition, depending on market price and product availability (Ranathunga et al. 2018). Corn DDGS has already been widely used in dairy cow feeding as a substitute for concentrate feeds. The use of DDGS as a substitute for corn, soybean, or rapeseed meal results in higher milk yield and protein content in milk, while no changes were observed in fat content or sensory quality of the milk (Benchaar et al. 2013, Gaillard et al. 2017). DDGS does not negatively affect the fermentation process occurring in the rumen of cows, thus the quality of milk is also not influenced (Chibisa et al. 2012, Pecka-Kiełb et al. 2023). To date, most studies have focused on the impact of DDGS on cow performance and milk composition. There is limited literature describing the effect of DDGS on the quality of colostrum in dairy cattle. Kennedy et al. (2019) found that supplementing with DDGS in the diets of beef cattle during late pregnancy can positively affect blood flow to the mammary gland, which in turn determines the quality of colostrum. A positive impact on sow's colostrum has also been observed with the use of DDGS in their diet (Xu et al. 2020, Corassa et al. 2022). The bioactive components in colostrum influence calves' development and modulate their immune system (Lopez et al. 2022, Silva et al. 2024). The immunological quality of colostrum is mainly assessed based on the level of IgG. IgG in the cow's colostrum is transferred through the digestive tract of newborn calves, determining the passive immunity of the neonates (Costa et al. 2021, Silva et al. 2024). The level of biologically active components in colostrum is associated with several factors, including nutrition during the dry period and the health status of the cows (Nowak et al. 2012). The results of other studies suggest the potential use of DDGS in the nutrition of dairy cows during pregnancy and lactation, either as an additive or as a substitute for concentrate feeds (Benchaar et al. 2013, Gaillard et al. 2017).

With proper incorporation of DDGS into the diet, one can expect not only an increase in the concentration of energy from fat or protein in the feed but also a potential improvement in milk composition. Additionally, DDGS can be a valuable source of phosphorus and sulfur, thereby lowering the DCAD of the diet, which in turn reduces the risk of diseases during the peripartum period (Clark et al. 2024). Therefore, the aim of the present study was to determine the effect of using DDGS as a substitute for concentrate feeds in the diets of cows during the dry period on the composition and physicochemical properties of the colostrum and the level of IgG in the serum of their calves.

Material and Methods

Animal housing conditions and nutrition

The study was conducted on a commercial dairy farm located in Wronów, Lower Silesia, Poland (latitude: 51°45′12″N, longitude: 16°26′42″E). Dry Hol-

Table 1. Ingredients of the feed rations for dry cows (TMR).

Ration ingredients	Groups			
	C	I	II	III
Corn silage (Kg)	33	33	33	33
Grass silage (Kg)	6	6	6	6
Straw (Kg)	0.5	0.5	0.5	0.5
Beet pulp (Kg)	8	8	8	8
Cereal meal (Kg)	2.5	1.15	0.5	0
Rapeseed meal (Kg)	2.5	2.25	1.3	1
Soybean meal (Kg)	2	1	1	0.6
Premix (g)	250	250	250	250
Acidic bicarbonate (g)	250	250	250	250
Limestone (g)	150	150	150	150
Fatra fat (g)	100	100	100	100
Yeast (g)	6	6	6	6
DDGS (Kg)	0	2.45	4	5.5

stein-Friesian cows were housed in a free-stall system in accordance with welfare requirements (Directive 2010/63/EU). The animals showed no signs of illness. All experimental procedures were licensed by the Second Local Ethics Committee for Experiments on Animals at the Wrocław University of Environmental and Life Sciences, Poland (license no. 166/2010).

From a herd of 350 cows, 60 were selected based on analogues (age: 3-5 years; average milk yield: 8,000 kg) three weeks before the expected calving date. They were assigned to 4 groups (15 cows each): Group C – traditional TMR diet; Group I – modified diet with 10% DDGS in dry matter, replacing grain, soybean, and rapeseed meal; Group II – DDGS content increased to 15% of the dry matter; and Group III – DDGS content increased to 20% of the dry matter. Colostrum was collected from cows in all groups into sterile containers from the first full milking after calving, and then transported to the laboratory at temperature of 4°C. Blood samples were drawn from the cows during colostrum sampling, as well as from their calves on the 3rd and 30th day of life. Blood was collected from the external jugular vein into a tube without anticoagulant.

TMR was basic feed for all Groups of dry cows (Table 1, 2). The diet was formulated according to INRA standards (IZ-INRA 2007). The ratio of concentrate to forage feed, calculated on a dry matter basis, was 29.5:70.5%, which provided a net lactation energy concentration of 0.79 UFL (5.62 MJ), intestinal digestible protein: 82 g of intestinal digestible protein for rumen-degradable nitrogen (PDIN) and 79 g of intestinal digestible protein for rumen-undegradable nitrogen (PDIE), as well as a fill value of 0.75 FVL per kg of TMR dry matter. This nutritional value allowed to produce approximately 8,000 kg of milk per lactation. Dry cows on this farm received limited TMR rations, amounting to 20 kg per cow, along with straw *ad libitum*. This type of the system is quite commonly used, as it helps to reduce labour and costs associated with producing a separate complete ration for the group of dry cows.

In the experimental groups, the DDGS content was gradually increased to 10%, 15%, and 20% of the dry matter, while simultaneously adjusting the amount of grain mix and extraction meals to maintain the isoenergetic and isoprotein balance of the TMR (Table 1). As a result, the proportion of concentrate feeds in the dry matter of the complete ration was very similar across all Groups, ranging from 29.5% to 30.4%. Due to this nutritional approach, the only differentiating factor in the diets in the experiment was the variable level of DCAD, which was gradually reduced from nearly 190 (Group C - control) to 10 mEq/kg dry matter (Group III) (Table 2).

The feeds used were subjected to chemical analysis (Table 3). The standards of the Association of Official Analytical Chemists (AOAC) were applied as follows: dry matter (AOAC method 934.01) (AOAC 2005), crude protein (CP, AOAC: 984.13) using a FOSS Tecator 2300 Kjeltec Analyzer Unit (FOSS Tecator, Höganäs, Sweden) to calculate crude protein (CP) as Kjeldahl N × 6.25 (AOAC 2005). Ether extracts (EE) were determined according to AOAC method 2005 920.39, using a Fibertec Tecator apparatus (Höganäs, Sweden). Crude ash (CA) was determined using AOAC method 942.05 (AOAC 2005, Britannica 2016). Crude fiber (CF) was measured using AOAC method 978.10. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured using a Fibertec Tecator apparatus (Höganäs, Sweden) according to Holst's method

Table 2. Composition and nutritional value of TMR (g/Kg DM).

Feed ration composition	Groups			
	C	I	II	III
Corn silage	521.8	522.5	522.2	515
Haylage	91	91.2	91.1	89.8
Straw	20	20	20	19.7
Distillers' grains	72.5	72.6	72.6	71.6
Cereal meal	94	43.3	18.8	0
Rapeseed meal	95.1	85.7	49.5	37.5
Soybean meal	76.1	38.1	38.1	22.5
Premix	9.7	9.7	9.7	9.6
Acidic carbonate	9.7	9.7	9.7	9.6
Limestone	5.8	5.8	5.8	5.7
Fatra fat	4.3	4.3	4.3	4.2
Yeast	0.1	0.1	0.1	0.1
DDGS	0	97	158.2	214.6
TOTAL	**1000**	**1000**	**1000**	**1000**
Energy UFL/kg DM	0.79	0.79	0.79	0.78
Protein PDIN	82	81	80	79
Protein PDIE	79	79	79	78
Filling value (LFU/kg DM)	0.75	0.75	0.75	0.74
DCAD mEq/kg DM	189	90	60	10

Table 3. Composition of feeds used in rations.

	Beet pulp silage	Corn silage	Yeast	Haylage	Soy	Rapeseed meal	Cereal meal	Straw	DDGS
DM[1]	21.06	36.73	29.03	35.24	88.42	88.34	87.31	92.79	91.82
Ash[1]	1.73	1.06	1.09	3.43	5.60	5.54	1.66	2.29	5.01
Protein[1]	2.08	2.70	7.36	8.76	48.09	37.99	11.13	4.51	24.87
Fiber[1]	4.52	6.07	5.62	10.87	6.12	13.70	3.16	44.25	8.72
NDF[1]	12.00	15.71	20.62	21.33	18.68	28.55	22.22	80.63	36.71
ADF[1]	5.31	7.71	6.83	11.65	8.40	18.58	4.33	50.02	11.86
Fat[1]	0.04	1.03	1.37	1.18	1.65	0.83	1.01	0.65	11.2
Ca[2]	0.94	0.65	0.57	1.47	2.63	5.21	0.87	3.57	1.68
P[2]	0.26	0.98	1.82	1.84	6.72	12.00	4.45	3.54	9.53
Mg[2]	0.45	0.50	0.56	0.84	2.90	4.48	1.04	0.81	3.78
Na[2]	0.14	0.13	0.10	0.29	0.27	0.23	0.53	0.39	4.14
K[2]	1.57	3.09	0.27	9.08	18.71	12.35	3.96	4.91	11.03
S[1]	0.05	0.06	0.09	0.15	0.40	0.83	0.18	0.15	0.35
Cl[1]	0.07	0.25	0.08	1.78	1.78	1.81	0.22	0.49	1.10

[1] %, [2] g/Kg

and AOAC 973.18 (Holst 1973), respectively. The content of Ca, Mg, K, and Na was determined using atomic absorption spectroscopy (AAS, Varian). Phosphorus was analyzed after wet digestion with nitric acid (HNO_3) and perchloric acid ($HClO_4$) using the ammonium vanadomolybdate method (Fick et al. 1979) with a Specol 11 spectrophotometer (Carl Zeiss, Jena) at a wavelength of 470 nm. Sulfur was measured nephelometrically according to the method of Bardsley and Lancaster (1960), and Cl was determined according to the Polish standard (PN-81/R-64780). The analytical data obtained allowed calculation of the nutritional

Table 4. Basic composition and levels of urea and cholesterol in cows' colostrum.

Parameters	Groups				P-value	SEM
	C	I	II	III		
SCC x 1000	6600	3140	9718[a]	2443[b]	0.039	1039.71
Fat (%)	9.83	8.59	8.33	9.13	0.665	0.452
Protein (%)	14.17	15.91	15.07	12.86	0.288	0.589
Lactose (%)	2.27	2.08	2.00	2.14	0.839	0.107
D.M. (%)	28.27	28.74	27.56	26.32	0.610	0.653
Urea (mg/L)	96.20	105.41	115.70	105.32	0.933	10.517
Cholesterol (mg/dl)	31.82[b]	42.34[a]	31.72	32.06	0.049	2.650

SEM – standard error of the mean, [a, b] values differ significantly between groups ($p<0.05$), [A, B] ($p<0.01$)

value of the diets for cows according to the INRA standard (2007), the mineral balance according to NRC (2001), and the DCAD calculation using the following equation: DCAD – dietary cation-anion difference was calculated using the formula (Na + K + 0.38 Ca + 0.30 Mg) – (Cl + 0.6 S + 0.5 P) (Horst and Goff 1997).

Analysis of colostrum and blood composition

The levels of fat, total protein, lactose, and dry matter in colostrum were determined using Infrared Milk Analyzer 150 (Bentley Instruments Inc., Chaska, MN, USA), while urea level was measured using Chemspec (Bentley Instruments Inc.). The somatic cell count (SCC) was determined using Somacount 150 (Bentley Instruments Inc.). Cholesterol level was measured using an enzymatic method with kits from BioSystem. The percentage of protein fractions, including serum albumin, α-, β-, and κ-casein, and α-lactalbumin, in colostrum was determined using polyacrylamide gel electrophoresis in the presence of sodium dodecyl sulfate (SDS-PAGE) according to the methodology of Pecka et al. (2012). The contents of Ca, Mg, K, Na, and P in colostrum were determined using atomic absorption spectroscopy (Varian AA240 FS), similarly to the method used for feeds (described above). Amino acid profiling was conducted using the AAA-400 amino acid analyzer from INGOS. The levels of immunoglobulins G, M, and A, as well as lactoferrin, were measured using ELISA tests from Bethyl Inc. Lactoperoxidase content was determined using tests from RANDOX.

Blood samples were centrifuged two hours after collection for 10 minutes at room temperature with a speed of 3000 × g. The obtained serum samples were frozen at -20°C until further analysis. In the serum samples, the level of IgG was determined using the ELISA method with kits from Bethyl, while the total protein level was measured using a Pentra 400 analyzer (Horiba ABX with ISE module) with reagents from ABX and Random.

Data Analysis

All obtained results were subjected to statistical analysis using one-way analysis of variance (ANOVA) in Statistica 13.3 [StatSoft Polska, Kraków, Poland]. The collected data were checked for normality using the Shapiro-Wilk test. Duncan's test was used to confirm the significance of differences between dietary groups. For all tests, differences were considered significant at $p<0.05$ and $p<0.01$.

Results

No significant changes were observed in the basic composition of cows' colostrum (Table 4). The highest dry matter content (28.74%) and protein content (15.71%) were found in colostrum of cows from Group I. The fat level in the colostrum from the experimental groups was lower compared to the control group, as was the lactose content. A significantly lower ($P<0.05$) somatic cell count (SCC) was observed in colostrum from Group III compared to Group II, while higher SCC was detected in colostrum from Groups C and I. An increase ($p<0.05$) in cholesterol level in colostrum from cows in Group I was observed compared to Group C.

The colostrum from cows in Groups II and III had a higher proportion of α-casein compared to Group I ($p<0.01$) (Table 5). The percentage of κ-casein in colostrum from Group I was higher ($p<0.05$) compared to the other groups. The use of DDGS in the diet of cows during the dry period did not significantly affect the percentage of serum albumin, β-casein, or α-lactalbumin in the colostrum.

Changes in the levels of IgG, IgM, IgA and lactoferrin, in the colostrum from cows in the experimental groups were observed (Table 6). The level of IgG was higher in Groups I, II and III, with a significant difference ($p<0.05$) in IgG content between Group II and Group C. A similar trend was noted for lactoperoxidase

Table 5. The proportion of protein fractions (%) in cows' colostrum.

Parameters	Groups				P-value	SEM
	C	I	II	III		
Serum albumin	9.77	7.11	8.17	6.98	0.210	0.529
α-casein	15.39	12.80^{B}	17.57^{A}	17.22^{A}	0.008	0.651
β-casein	9.49	10.14	9.48	10.94	0.710	0.509
κ-casein	4.00^{b}	5.72^{a}	3.99^{b}	4.17^{b}	0.017	0.279
α-lactalbumin	8.29	8.14	8.38	7.64	0.858	0.326

SEM – standard error of the mean, $^{a, b}$ values differ significantly between groups ($p<0.05$), $^{A, B}$ ($p<0.01$)

Table 6. Levels of immunoglobulins, lactoferrin, and lactoperoxidase in cows' colostrum.

Parameters	Groups				P-value	SEM
	C	I	II	III		
IgG (mg/ml)	26.77^{b}	34.97	41.24^{a}	35.99	0.039	1.788
IgA (mg/ml)	2.80^{b}	4.06^{a}	4.26^{a}	3.86	0.044	0.216
IgM (mg/ml)	4.05^{b}	5.29^{a}	4.70	5.18^{a}	0.047	0.315
Lactoferrin (mg/ml)	4.28^{Bb}	5.77^{a}	6.64^{A}	6.10^{A}	0.002	0.235
Lactoperoxidase (U/L)	2.11	2.54	3.47	3.29	0.048	0.222

SEM – standard error of the mean, $^{a, b}$ values differ significantly between groups ($p<0.05$), $^{A, B}$ ($p<0.01$)

Table 7. Amino acid levels in cows' colostrum (g/kg DM).

Parameters	Groups				P-value	SEM
	C	I	II	III		
Asp	14.51^{a}	13.71	12.38^{b}	12.58^{b}	0.043	0.324
Thr	11.55^{a}	10.66	9.71^{b}	9.92^{b}	0.048	0.259
Ser	14.06^{a}	13.07	11.72^{b}	12.04^{b}	0.042	0.325
Glu	28.35^{a}	27.39	24.76^{b}	24.38^{b}	0.045	0.602
Pro	16.83	17.37	15.02	14.88	0.108	0.422
Gly	5.43^{a}	5.07	4.49^{b}	4.60	0.033	0.089
Ala	6.83	6.47	5.86	5.91	0.131	0.170
Val	11.95^{A}	11.31	9.99^{B}	7.92	0.145	0.318
Ile	6.46	6.54	5.92	5.88	0.150	0.129
Leu	15.68^{a}	15.43	13.71^{b}	13.82^{b}	0.013	0.307
Tyr	8.32	7.98	7.25	7.26	0.129	0.195
Phe	7.27	7.12	6.45	6.46	0.153	0.162
His	4.26	4.15	3.82	3.63	0.084	0.098
Lys	14.50	13.85	12.59	12.62	0.107	0.333
Arg	8.65^{a}	8.21	7.29^{b}	7.37^{b}	0.016	0.182
Cys	2.87	2.73	2.65	2.38	0.122	0.074
Met	3.03^{a}	3.21^{A}	3.01^{a}	2.65^{Bb}	0.007	0.061
Try	2.81^{a}	2.58	2.03^{b}	2.27	0.023	0.097

SEM – standard error of the mean, $^{a, b}$ values differ significantly between groups ($p<0.05$), $^{A, B}$ ($p<0.01$)

content. Although higher levels of lactoperoxidase were detected in the colostrum from cows in Group I and III compared to Group C, with no significant differences between the groups. The colostrum from cows receiving DDGS in their diet had higher level of IgA, with significant differences ($p<0.05$) between Groups I and II versus group C. Additionally, the content of IgM was higher in the colostrum from Groups I, II, and III compared to control group, with significant differences ($p<0.05$) between Groups I and II versus Group C.

Table 8. Mineral content in cows' colostrum (g/kg).

Parameters	Groups				P-value	SEM
	C	I	II	III		
Ca	1.84	1.74	1.79	1.58	0.383	0.051
Mg	0.33	0.28	0.33	0.28	0.306	0.012
K	1.23^{Bb}	1.98^{A}	1.92^{a}	1.36^{Bb}	0.000	0.062
Na	0.60^{b}	0.51^{B}	0.77^{Aa}	0.51^{B}	0.003	0.029
P	1.98	2.14	1.97	1.93	0.418	0.046

SEM – standard error of the mean, $^{a, b}$ values differ significantly between groups ($p<0.05$), $^{A, B}$ ($p<0.01$)

Table 9. Total serum protein and IgG in cows and calves.

Parameters	Sampling date (days of life)	Groups				P-value	SEM
		C	I	II	III		
				Cows			
Total protein (U/L)	1st day	73.02^{Aa}	69.67	66.28^{B}	68.14^{b}	0.003	1.057
IgG (mg/ml)	1st day	24.88	28.41	26.21	26.32	0.736	0.708
				Calves			
Total protein (U/L)	3rd day	$53,76^{b}$	57.99	65.85^{a}	58.49	0.045	3.082
	30th day	51.63^{b}	53.45	55.13^{a}	55.31^{a}	0.036	2.890
IgG (mg/ml)	3rd day	9.56^{B}	14.61^{Aa}	16.81^{Aa}	10.63^{b}	0.009	0.359
	30th day	6.67^{b}	7.60	8.61^{a}	8.28	0.048	0.899

SEM – standard error of the mean, $^{a, b}$ values differ significantly between groups ($p<0.05$), $^{A, B}$ ($p<0.01$)

The colostrum from cows in Group C had lower level of lactoferrin compared to Groups I ($p<0.05$), and II, and III ($p<0.01$).

The amino acid profile in the colostrum of cows fed diets with DDGS was altered (Table 7). A decrease in the levels of Asp, Thr, Ser, Glu, Leu, and Arg was observed in the colostrum from the experimental groups ($p<0.05$), with higher concentrations found in Group C. In Group II, a decrease in Gly and Try was noted compared to the colostrum from Group C ($p<0.05$). The content of Val in the colostrum from Group C was higher ($P<0.01$) compared to the colostrum from Groups II and III. Conversely, the level of Met in Group III was lower compared to Groups C, and II ($p<0.05$), and Group I ($p<0.01$).

The content of analysed mineral components in the colostrum indicates only slight variations (Table 8). A modestly lower calcium level was observed in the colostrum from the experimental groups. Magnesium content ranged from 0.28 g/L (Groups I and III) to 0.33 g/L (Groups C and II), with no significant differences between the groups. In the colostrum from cows fed diets with 10% and 15% DDGS (Groups I and II), a higher potassium level was found compared to the colostrum from Groups C and III. Conversely, sodium levels were lower in the colostrum from Groups I and III ($p<0.01$) and Group C ($p<0.05$) compared to Group II. Higher phosphorus content was observed in the colostrum from Group I, while the amount was similar in the other groups. The difference between Groups I and III was significant ($p<0.05$).

The use of DDGS in the diet of cows before calving resulted in changes in total protein and IgG levels in the serum of cows and calves (Table 9). The highest serum protein content was observed in Group C, significantly higher compared to that in Group II ($p<0.01$) and Group III ($p<0.05$). Opposite trends were observed in the calves on the 3rd day of life. In calves from the experimental groups, an increase in total protein levels was noted. A significantly higher ($p<0.05$) serum protein level was found in Group II compared to that in Group C. Similar trends were observed for serum protein content in calves on the 30th day of life. The protein level in Groups II and III was higher ($p<0.05$) compared to the control group. IgG serum levels were similar across all the groups, with the highest concentration in Group I. In calves, on the 3rd day of life, higher IgG serum levels were found in experimental groups. The differences between Groups I and II compared to the control group were significant ($p<0.01$). The IgG serum level in Group III was similar to that in the control group. On the 30th day of life, IgG serum

levels in Groups I and II showed a significant decrease by approximately 50%. While IgG serum levels also decreased in Group C and Group III, the reduction was less substantial, ranging from 20% to 30%. As on the 3rd day of life, calves in Group III had the highest IgG serum levels, which were significantly higher ($p<0.05$) compared to those in Group C.

Discussion

Adding DDGS to the diets of dry cows as a substitute for concentrates affected the quality of the colostrum they produced, which in turn impacted how well its components were utilized by newborn calves. The quality of the colostrum is significantly influenced by the nutrition of cows during the dry period (Nowak et al. 2012, Silva et al. 2024). A few weeks before calving, the process of colostrogenesis starts, during which immunoglobulins are transferred from the mother's bloodstream to the mammary gland secretions (Nowak et al. 2012, Kennedy et al. 2019). The intensity of this process peaks in the final days of the dry period. The quality of the colostrum fed to calves on their first day of life, particularly its immunoglobulin content, is crucial for effective absorption and, as a result, for ensuring the calves' level of passive immunity (Lopez and Heinrichs 2022, Silva et al. 2024). DDGS is recognized as a valuable source of energy and rumen undegradable protein (RUP) (Dias et al. 2024). The quality of colostrum is influenced by the nutrition of cows during the dry period and by metabolic disorders that can occur around calving. These disorders often result from imbalances in the diet, affecting not only protein and energy levels but also the supply of minerals and the proper balance of cations and anions (Nowak et al. 2012). Replacing dietary concentrates (barley meal, soybean meal, and canola meal) with DDGS from corn resulted in a consistent reduction in the DCAD of the diet, lowering it from 189 to 90, 60, and 10 mEq/kg dry matter depending on DDGS quantity added. Previous studies have demonstrated that reducing DCAD to near-zero or negative levels can help minimize metabolic disorders around calving. This improvement in the cows' metabolic status can, in turn, lead to the production of higher-quality colostrum (Penner et al. 2008, Clark et al. 2024).

Feeding DDGS to cows during the late stages of pregnancy may improve blood flow to the mammary gland, which can enhance colostrum quality and calf rearing results. Research on beef cattle supports this effect (Kennedy et al. 2019). In cows, the syndesmochorial placenta prevents the transfer of immunoglobulins to the fetal bloodstream before birth. As a result, calves are born without any natural immunity, a condition known as agammaglobulinemia. To protect them, it is crucial to provide high-quality colostrum within the first 24 hours of their life. This process, called passive immunity, involves the absorption of maternal immunoglobulins from the colostrum into the calf's small intestine within that critical 24-hour period. A serum IgG level above 10 mg/ml in calves is considered the minimum required to effectively lower their risk of illness and mortality (Nowak et al. 2012, Godden et al. 2019). Additionally, the total protein level in calf serum serves as an important indicator of their overall immunity (Wilm et al. 2018). After colostrum is administered, the level of passive immunity in calves can vary widely. This variability depends largely on the total amount of immunoglobulins consumed and how well they are absorbed within the first 24 hours of life. IgG in calf serum has a half-life of about 20 days, during which the level remains fairly constant (Murphy et al. 2014). Therefore, it is crucial to ensure that the colostrum provided to calves is of high quality. Colostrum in cattle contains immunoglobulins IgG, IgA, and IgM, which make up approximately 85% to 90%, 5%, and 7% of the total immunoglobulins, respectively (Godden et al. 2019). All immunoglobulins in the colostrum are essential for the immune system of calves. They help prevent the excessive growth of microorganisms, stop them from sticking to endothelial surfaces, neutralize toxins, and aid in the inactivation of viruses. Additionally, the colostrum contains lactoferrin, which provides important antibacterial protection to calves (Wilm et al. 2018, Lopez and Heinrichs 2022, Silva et al. 2024). In our studies, incorporating DDGS into the cows' diets achieved the target levels of IgG and protein in the serum of calves on both the 3rd and 30th days of life. Notably, calves in Group II, showed a significant increase in IgG levels. Moreover, the colostrum from DDGS-fed cows had higher levels of immunoglobulins and lactoferrin, which likely enhanced the calves' absorption of IgG.

The available literature does not include studies on how using DDGS in the diets of dry cows affects the composition and quality of colostrum. Most research has concentrated on the effects of DDGS on milk production traits in lactating cows. Nevertheless, including DDGS at 10% or 20% dry matter as a replacement for soybean meal and ground corn has been shown to improve feed efficiency and increase protein and fat levels in milk (Anderson et al. 2006). Using 18% DDGS as a protein source had minimal effects on cow performance and milk composition. In our studies, DDGS did not affect the levels of colostrum protein, fat, dry matter, lactose, or urea. The only change observed was an increase in cholesterol levels in Group I. Mjoun et al.

(2010) found that adding DDGS to the diets of cows with reduced fat content (10%, 20%, and 30% of dry matter) led to higher serum cholesterol concentrations in the experimental groups. Cholesterol colostrum levels decreased as lactation progressed. High colostrum cholesterol concentrations in colostrum are important for newborns because cholesterol is crucial for their development. It is a key component of cell membranes, a precursor for steroid hormones, and supports the formation and development of the central nervous system (Dewettinck et al. 2008, Contarini et al. 2014). Colostrum collected immediately after calving is composed of up to 60% protein of DM. Typically, this colostrum contains about 80% whey proteins and 20% casein proteins. The casein proteins in the colostrum can be used as an energy source for newborns, support immune functions, help to the absorption of other biologically active peptides, and possess antibacterial and anti-inflammatory properties. Additionally, caseins are involved in transporting minerals and trace elements (Playford and Weiser 2021, Silva et al. 2024). The inclusion of DDGS in cow diets leads to higher levels of casein in milk (Thanh et al. 2015, Christen et al. 2020). However, Liu et al. (2001) reported that DDGS increased the proportion of whey proteins while decreasing the proportion of casein proteins in milk, without altering the relative proportions of different protein fractions. In our own studies, we observed that DDGS increased the colostrum levels of α-casein in Groups II and III, and elevated κ-casein levels in Group I.

Colostrum is the main source of minerals for newborn calves. It is rich in calcium (1.53-2.0 g/L), magnesium (0.12-0.31 g/L), phosphorus (1.75-2.26 g/L), and sodium (0.40-0.95 g/L) (Kume and Tanabe 1993, Pecka-Kiełb et al. 2012). Calcium is a crucial mineral for the development of the skeleton, and calves can absorb up to 99% of this it during the first 10 days of life (Silva et al. 2024). Research on the mineral composition of the colostrum is limited and often inconsistent, which makes interpreting results and drawing clear conclusions challenging. In our studies, adding DDGS to the diets of cows before calving did not affect the colostrum levels of calcium (Ca) and magnesium (Mg). We observed only minor changes in the levels of potassium (K), sodium (Na), and phosphorus (P). These levels were consistent with those reported by other researchers (Kume and Tanabe 1993, Pecka-Kiełb et al. 2012). Calves receive amino acids from their mother through the placenta while they are still in the womb (Hammon et al. 2012). After birth, the colostrum becomes the only source of amino acids for the calves. High-quality colostrum is crucial because it supports the gluconeogenesis process in the calves' bodies and meets their high protein requirements (Playford and Weiser 2021, Silva et al. 2024). The amino acid levels in a calf's blood reflect the amounts found in the colostrum or milk. Using high-protein DDGS in the cows' diet increases the overall levels of both essential and non-essential amino acids in the cows' serum (Maxin et al. 2013). Li et al. (2024) studied how adding DDGS to the diet affects amino acid levels in milk. Their results showed that the experimental groups with DDGS had higher amino acid levels compared to the control group. Moreover, supplementing DDGS with protected methionine and lysine resulted in even higher amino acid levels in the milk. In the present study we found that using DDGS in the diets of dry cows led to lower amino acid levels in the colostrum, which is consistent with findings reported by other researchers (Goi et al. 2023).

Conclusions

Using DDGS as a replacement for barley meal, soybean meal, and canola meal in cow diets influences the colostrum immunoglobulin levels, but not affects basic colostrum components. Using 15% DDGS in the diet (Group II) led to higher levels of IgG and IgA in the colostrum. Additionally, the colostrum from cows in all DDGS groups had elevated levels of all immunoglobulin classes. The colostrum from cows fed with DGGS also had increased levels of lactoferrin. However, the colostrum levels of analysed amino acids were slightly lower. The improved immunological quality of colostrum from cows in the experimental groups resulted in higher IgG levels in their calves' serum on the 3rd day of life. In addition, on the 30th day after birth, calves from cows fed 15% DDGS showed even higher IgG levels.

In summary, DDGS can be used as a substitute for concentrate feeds in dry cow diets at levels from 10% to 20% dry matter enhancing the colostrum quality. Moreover, since calves from the cows fed 15% DDGS had the highest IgG levels, this concentration should be considered as optimal. Using DDGS at this concentration may improve passive immunity of calves and be of benefit for their overall rearing outcomes.

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