

## Nutritional value of high moisture corn silage in the diet of *Holstein* cows

[Valor nutritivo da silagem de grãos úmidos de milho na alimentação de vacas da raça *Holandesa*]

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### ABSTRACT

Five Holstein cows were distributed in a 5x5 latin square design to assess the effect of replacement levels of dry ground corn grain (DGCG) by high moisture corn silage (HMCS) on intake, total nutrient digestibility and plasma glucose, according to the following treatments: 1) 100% DGCG; 2) 75% DGCG and 25% HMCS; 3) 50% DGCG and 50% HMCS; 4) 25% DGCG and 75% HMCS; 5) 100% HMCS. The experiment lasted 70 days, divided into five phases of 14 days each. The digestibility was obtained using chromic oxide (Cr<sub>2</sub>O<sub>3</sub>) as the indicator. Fecal samples were collected twice daily and blood samples were collected on the last day of each period before the first meal (0h) and 2h, 4h, 6h and 12h after the meal. There was no effect (P>0.05) on the intake of dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and starch. The total apparent digestibility of DM, crude protein (CP), NDF and ADF were not affected (P>0.05) by the treatments, as well as the plasma glucose concentration. However, there was a decreased linear effect (P<0.05) for the protein intake and increased linear effect (P<0.05) for starch digestibility, as the level of HMCS was increased in the diets.

Keywords: starch, digestibility, glucose, chromium oxide, processing

### RESUMO

Cinco vacas da raça *Holandesa* foram distribuídas em quadrado latino 5x5 com o objetivo de se avaliar o efeito de níveis de substituição do grão seco de milho (GSM) pela silagem de grãos úmidos de milho (SGUM) sobre consumo, digestibilidade total dos nutrientes e glicose plasmática, o que constituiu os tratamentos: 1) 100% GSM; 2) 75% GSM e 25% SGUM; 3) 50% GSM e 50% SGUM; 4) 25% GSM e 75% SGUM; 5) 100% SGUM. O período experimental durou 70 dias, divididos em cinco fases de 14 dias. A digestibilidade foi obtida utilizando-se óxido crômico (Cr<sub>2</sub>O<sub>3</sub>) como indicador. Foram colhidas amostras fecais duas vezes por dia, bem como amostras de sangue no último dia dos períodos, antes da primeira refeição (zero hora), duas, quatro, seis e 12 horas após a refeição. Não houve efeito (P>0,05) sobre o consumo de matéria seca (MS), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e amido. A digestibilidade aparente total da MS, a proteína bruta (PB), a FDN e a FDA não foram afetadas (P>0,05), assim como a concentração de glicose plasmática. Houve efeito linear decrescente (P<0,05) para consumo de PB e linear crescente (P<0,05) para digestibilidade do amido, à medida que se aumentou a inclusão de SGUM.

Palavras-chave: amido, digestibilidade, glicose, óxido crômico, processamento

### INTRODUCTION

The dairy herds, especially high production ones, rely heavily on concentrated foods in their diet,

with corn as the common ingredient in such concentrate rations. Also due to the substantial use of dry corn, the cost of food has become very significant in dairy farms. Thus, high moisture corn silage is an interesting alternative to

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substitute dried ground corn, to lower the production costs as well as to improve the efficiency in using starch.

The benefits of processing cereal grains have shown an increase in ruminal starch digestibility, resulting in higher amounts of energy available for the development of the microbial population, which result in a greater production of short-chain fatty acids. Among the processing methods used, the chemical-physical ones, such as flocculation or high moisture silage, have been quite effective (Owens *et al.*, 1997).

Starch stored in the form of silage, of the whole plant as well as of moist grains, is digested (most of it) faster in the rumen (Owens *et al.*, 1986). The energy provided by the digestion of starch in the rumen is important since the microbial protein synthesis may be limited by the low availability of nonstructural carbohydrates and the lack of carbon skeletons, which are used in the formation of microbial cells (Mello Jr., 1991).

Glucose is a high priority, due to its central role in the mammary gland, as it supplies carbon, hydrogen and oxygen for the synthesis of lactose, which is the major osmotic regulator in the milk volume produced by cows (Bermudes *et al.*, 2003).

Therefore, this study investigated the effects of using moist corn silage instead of dried corn in the diets of lactating Holstein cows, on the intake, nutrient digestibility and glucose.

## MATERIAL AND METHODS

The experiment was conducted at the University of Marília - Unimar, Faculty of Agricultural Sciences, in the Dairy Cattle sector. The study assessed different replacement levels (0, 25, 50, 75 and 100%) of dry ground corn grain (DGCG) for high moisture corn silage (HMCS). Five Black and White primiparous Holstein cows – PO, at 84 postpartum days and weighing 508 live kg, on average, were distributed in a 5x5 Latin Square design.

The diets were composed of sugar cane and grass hay silage as feed and soybean concentrates as protein source and ground corn and/or moist ground corn silage as energy sources. They were formulated to be isonitrogenous and isoenergetic, comprising the following treatments based on dry matter: 1) 100% DGCG; 2) 75% DGCG and 25% HMCS; 3) 50% DGCG and 50% HMCS; 4) 25% DGCG and 75% HMCS; 5) 100% HMCS.

Table 1 shows the chemical composition of the ingredients used to produce the diets. Table 2 shows the percentages of ingredients in the different diets, as well as their chemical composition.

Table 1. Chemical composition of the feeds used to compose the experimental diets (% DM)

Feed	DM	MM	CP	EE	NDF	ADF	Starch
Corn	86.66	2.89	9.50	4.88	16.31	4.63	69.25
HMCS	71.78	4.00	7.60	6.85	13.74	3.13	74.69
Soybean bran	87.63	8.25	4.84	1.73	18.72	1.15	5.51
Sugar cane silage	24.19	6.83	3.41	2.31	74.45	44.32	
Hay	86.92	7.29	9.98	1.25	76.72	43.04	

DM: dry material; MM: mineral matter; CP: Crude protein; EE: ethereal extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; HMCS: high moisture corn silage.

The diets were formulated according to the recommendations by the National Research Council (National..., 2001), to meet the requirements of that category for the production of 30 L/day, consisting of 60% concentrate and 40% animal food. Feeding was *ad libitum*, three times a day (6h00min, 13:00min and 18:00min), allowing a surplus of approximately 10% of that offered.

To produce the moist corn silage, the corn grain harvest was performed after the physiological maturity stage, with approximately 28% of humidity. After the harvest, the grains were ground and stored in 200-liter capacity plastic containers, following the systematic compression and sealing of the ensiling process.

The experimental phase lasted 70 days, divided into five periods of 14 days, with the first ten

days for diet adaptation and the last four days to gather data and samples. The animals were kept in “Tie stall” type installation, with sand beds, fitted with individual feeders and watering places and were released at least an hour a day to exercise in a paddock next to the facility. They were dewormed and given a dose of vitamin A, D and E before the start of the study. The cows were milked twice daily (18:00h and 6:00h).

The food remains were removed and weighed before providing the first meal (6h00min). The food samples used were collected and frozen (-10 °C) at the end of each period, then dried in forced oven-ventilation at 55 °C for 72 hours, ground in a Willey type mill, using a 1.0 mm sieve and stored in plastic polyethylene pots, properly identified for the laboratory tests. For determining the feces and feed, the dry matter

(DM), fiber in acid detergent (FAD), ether extract (EE) and mineral material (MM), the methodology described by Silva (1990) was used. The crude protein (CP) was obtained by the combustion of the samples with the Dumas method, using a Leco® nitrogen auto-analyzer (Leco Corporation, St. Joseph, MI, USA) model FP-2000 nitrogen analyzer. For the determination of the neutral detergent fiber (FND) the methodology proposed by Van Soest *et al.* (1991) with thermo-sTab was used.  $\alpha$ -amylase and urea were used in order to reduce the starch contamination and to facilitate filtering.

Starch was determined by the methodology described by Knudsen (1997) and metabolizable energy was calculated according to Sniffen *et al.* (1992).

Table 2. Composition of experimental diets with replacement levels of dry corn grain for high moisture corn silage (HMCS)

Ingredients <sup>1</sup>	Experimental Diets				
	0% HMCS	25% HMCS	50% HMCS	75% HMCS	100% HMCS
Corn	34.21	25.59	17.03	8.59	-
HMCS	-	8.56	17.13	25.78	34.12
Soybean bran	24.18	24.17	24.14	24.18	24.07
Sugar-cane silage	24.27	24.27	24.15	24.12	24.46
Hay	14.54	14.61	14.74	14.74	14.55
Mineral nucleus <sup>2</sup>	2.79	2.80	2.81	2.82	2.80
<b>Composition</b>					
Dry material <sup>1</sup>	53.38	52.92	52.45	51.56	51.08
Metabolizable Energy <sup>3</sup>	2.41	2.41	2.42	2.43	2.43
Crude protein <sup>1</sup>	17.58	17.41	17.25	17.10	16.87
Ether extract <sup>1</sup>	2.83	3.00	3.16	3.34	3.56
Fiber in neutral detergent <sup>1</sup>	39.33	39.70	38.94	38.56	38.57
Fiber in acid detergent <sup>1</sup>	21.78	21.37	21.55	21.32	21.34
Starch <sup>1</sup>	25.02	25.44	25.91	26.53	26.81

<sup>1</sup>% MS. <sup>2</sup>Mineral nucleus: 16% Ca; 10% P; 2,5%mg; 3,5% S; 10% Na; 1080mg Cu; 4250mg Mn; 4025mg Zn; 80mg I; 64mg Co; 32mg Se. <sup>3</sup>Mcal/kg MS.

The apparent digestibility of MS DM, Starch, NDF, ADF and CP were obtained by an indirect method using chromic oxide (Cr<sub>2</sub>O<sub>3</sub>) as an indicator using 10 g per animal per day for 7 days, and was administered orally during the adaptation period and during the 4 collection days. Feces were collected twice daily after milking (morning and late afternoon), directly

from the rectum during the last four days of each period. Chromic oxide was determined by the energy dispersive X-ray fluorescence (EDXRF) technique, using the methodology described by Almeida *et al.* (2007).

The apparent digestibility was calculated with the following formula:

$$\text{Nutrient Dig.} = 100 - 100 \times \left( \frac{\% \text{ Feed indicator}}{\% \text{ Feces indicator}} \times \frac{\% \text{ Nutrient in the feces}}{\% \text{ Nutrient in the food}} \right)$$

$$\text{Digestibility of DM} = 100 - 100 (\% \text{ of indicator} / \% \text{ Feces indicator})$$

Blood collection was performed on the last day of each period (14 days). The samples were collected from the jugular vein at 0, 2, 4, 6 and 12 hours after the first meal of the day and immediately sent to the laboratory for glucose analysis, using the automated enzymatic method (LabMax 240®).

For glucose, the experiments were analyzed as repeated measures, ascribing the levels of moist corn silage in the diet to the main parcels and the harvest times for repeated measures. For the characteristics that showed significant treatment effects in the variance analysis ( $P < 0.05$ ), they were studied by means of regression, and the linear, quadratic and cubic effects were tested. The data were analyzed by Statistical Analysis Genetics Epidemiology - SAGE, version 9.0.

## RESULTS AND DISCUSSION

Table 3 shows the data on the average daily intake of dry matter and nutrients. There was no effect on the level of replacement of dry corn grain (DGCG) for high moisture corn silage (HMCS) on dry matter (DM) intake, neutral detergent fiber (NDF), acid detergent fiber (ADF) and starch. There was a decreased linear effect for the intake of crude protein (CP), with the increase of HMCS in the diets.

Table 4 shows that there was no effect of the treatments on the mean daily intake of digestible nutrients: DM, CP, NDF, ADF and starch.

Table 3. Daily intake of dry matter (IDM), crude protein (ICP), neutral detergent fiber (INDF), acid detergent fiber (IADF) and starch (IS)

Variables <sup>1</sup>	Experimental diets					Average	CV	Probability		Equation	R <sup>2</sup>
	0% HMCS	25% HMCS	50% HMCS	75% HMCS	100 % HMCS			L	Q		
IDM	17.52	18.94	16.78	16.95	15.40	17.11	9.02	NS	NS	-	-
ICP	3.08	3.29	2.89	2.90	2.59	2.95	9.84	0,039	NS	Y=3.227- 0.0054x	0.696
INDF	6.89	7.52	6.53	6.53	5.94	6.68	9.86	NS	NS	-	-
IADF	3.81	4.05	3.62	3.61	3.29	3.67	9.70	NS	NS	-	-
IS	4.38	4.81	4.35	4.50	4.13	4.43	9.45	NS	NS	-	-

HMCS: high moisture corn silage; CV: coefficient of variation; L: Linear effect probability effect; Q: quadratic effect probability; NS: Not Significant. <sup>1</sup>Average daily intake: kg/cow.

Table 4. Daily intake of digestible nutrients: dry matter (DMD), crude protein (CPD), neutral detergent fiber (DNFD), acid detergent fiber (ADFD) and starch (SD)

Variables <sup>1</sup>	Experimental diets					Average	CV	Probability		Equation	R <sup>2</sup>
	0% HMCS	25% HMCS	50% HMCS	75% HMCS	100 % HMCS			L	Q		
DMD	11.69	13.59	11.63	12.02	11.05	12.00	15.88	NS	NS	-	-
CPD	2.20	2.45	2.10	2.18	1.93	2.17	16.40	NS	NS	-	-
DNFD	3.46	4.14	3.17	3.35	3.06	3.44	18.74	NS	NS	-	-
ADFD	1.65	2.17	1.62	1.79	1.57	1.76	22.63	NS	NS	-	-
SD	3.65	4.22	3.85	3.94	3.76	3.89	13.75	NS	NS	-	-

HMCS: Moist corn grains silage; CV: coefficient of variation; L: Linear effect probability effect; Q: quadratic effect probability; NS: Not Significant. <sup>1</sup>Average daily intake: kg/cow.

According to Van Soest (1994), the intake is regulated by chemostat mechanisms and physical limitations of the digestive system.

Physical factors operate by the limits on the ability of the rumen and reticulum and the time the food spends in the organ (Jorge *et al.*, 2002).

In this study, it is possible that the factors regulating intake were not physical, considering

that the diet was composed of 60% concentrate, containing rapid ruminal fermentation ingredients, which would not completely fill the rumen.

It is then possible that the animals used the energy level of the diet as a regulatory intake mechanism, since the intake of digestible starch did not differ in the treatments (Table 4). Animals satisfied with the amount of energy

consumed do not need to fill the entire volume of the gastrointestinal tract to meet their daily nutritional requirements.

Compared to dry grains, the high moisture corn silage has a higher amount of energy. With processing, the starch is more exposed to the attack of ruminal microorganisms and enzymes, thus increasing digestibility. Thus, the more starch digested, the more the digestion products are absorbed and the animal reaches satiation.

Ferreira *et al.* (2007), in order to evaluate the selection of cattle diet, studied foods with different energy content (thin, thick and flaked corn) and found no difference in the intake of degradable starch in the treatments.

Overton *et al.* (1995) reported decreased linear effect for DM intake, when corn was replaced by barley in the diet of lactating dairy cows. Santos *et al.* (1997) observed a reduction in the DM

intake, working with sorghum and barley, processed in different ways (dry-rolled and flaked) in the diets of dairy cows. Aldrich *et al.* (1993) also reported lower dry matter intake for the treatments using high moisture corn grains, when compared with dry corn grains. However, several studies can be found in the literature that assessed different sources of starch and forms of grain processing and found no difference in DM and nutrient intake (Passini *et al.*, 2002; Zeoula *et al.*, 2003; Simas *et al.*, 2008).

The decreasing linear effect found for CP intake may be related to a lower DM intake and a lower level of CP, which although not statistically different, was numerically lower for treatments with HMCS higher levels when compared to the diet that only consisted of DGCG. This result could have contributed to the effect found for the CP (Table 5).

Table. 5. Apparent digestibility in % of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and starch

Variables	Experimental Diets					Average	CV	Probability	
	0% HMCS	25% HMCS	50% HMCS	75% HMCS	100 % HMCS			L	Q
DM	67.81	72.11	69.50	70.94	71.76	70.42	6.18	NS	NS
CP	72.30	74.75	73.02	75.33	74.32	73.94	6.09	NS	NS
NDF	51.36	55.70	48.94	51.41	51.60	51.80	12.02	NS	NS
ADF	44.62	54.11	45.07	49.46	47.86	48.23	17.17	NS	NS
Starch	84.27	88.12	89.05	88.07	91.26	88.15	6.28	0.0026 <sup>1</sup>	NS

HMCS: High moisture corn silage; CV: coefficient of variation; L: Linear effect probability; Q: Quadratic effect probability; NS: Not significant. <sup>1</sup>Y = 85.366 + 0.0557 x; R<sup>2</sup> = 0.1319

The replacement level of DGCG by HMCS had no effect on the apparent digestibility of DM, CP, NDF and ADF.

There was an increased linear effect for the apparent digestibility of starch, when the level of HMCS was increased in the diets.

In starch-rich diets, the microbial population is mainly amylase and these microorganisms compete for the soluble carbohydrates, for the final products of starch and hemicellulose hydrolysis, especially with lower pH, producing greater amounts of propionate and lactate (Van Soest *et al.*, 1994; Nussio *et al.*, 2006).

It is possible that the unfavorable environment for microorganisms that degrade fiber, low pH due to the amount of starch in the diet (25%), was the reason for the results obtained for the

apparent digestibility of FND and FAD. These two components represent a large part of the DM diets and with the CP they probably contributed to the insignificant effect on the DM digestibility.

The result obtained for the CP digestibility can be attributed to the absence of a non-protein nitrogen source, as there was no urea in the diet, readily soluble in the rumen, which would favor food degradation and probably the subsequent protein synthesis in the rumen.

Jorge *et al.* (2002) evaluating two sources of slow and fast degradation starch in the rumen, justified the digestibility increase of CP, as the slow degradation source was replaced with the increased use of urea in these diets. Zeoula *et al.* (1999), considering two sources of starch and N of low and high ruminal degradability, also

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attributed the digestibility increase of CP to more favorable conditions for microbial growth and subsequent fermentation, promoted by high degradability N sources (canola bran + urea).

The main obstacle for the digestion of starch is the difficulty of the ruminal microorganisms and the large intestine or small intestine enzymes in accessing the starch of the grain. This difficulty is caused by the particle size and the chemical properties of starch. With processing, some changes occur, minimizing the factors that contribute to the lower utilization of the grain starch.

In the moist grain silage process, not only the particle size is reduced, resulting in a greater contact surface with the ruminal microorganisms and enzymes, but there are also alterations in the structure of starch granules, with changes in the plant tissue and its surface (disruption of the protein matrix and formation of pores).

According to Mello Jr. (1991), the changes caused by the processing are responsible for the greater ruminal starch digestion of grains. The digestibility of starch increases as the starch, derived from the rapid ruminal degradation source, is increased in the diet (Overton *et al.*, 1995).

The results presented by San Emeterio *et al.* (2000), that evaluated the effect of processing (levels of grinding and moist grain silage) in the diet of lactating Holstein cows, are similar to those obtained in this study. No differences were observed for the digestibility of DM, NDF, and ADF in the treatments, however the digestibility of starch was superior for the treatment with HMCS when compared to dry grains. The authors also conclude that the best result obtained for the digestibility of starch was due to the participation of moist grain silage in the diet and also due to the reduced particle size.

However, Passini *et al.* (2002) reported that the effect of corn conservation on moist grain silage

is superior to the forms of breaking and grinding, because the grinding increased the effective degradability of DM by 40.2%, while the silage increased 72.8%.

Wilkerson *et al.* (1997), who also worked with Holstein cows, assessing HMCS in relation to dry grains and different particle sizes (ground and rolled), found no difference in the treatments for the digestibility of NDF and ADF. However, they had better DM and CP digestibility for the cows fed with HMCS, regardless of the particle size.

However, the average CP value in the diets was 20.4%, while in the present study it was 17.2%, which, according to Rodriguez *et al.* (1997), resulted in a greater daily intake of CP, diluting the effect of endogenous N and increasing the digestibility of CP for diets richer in N.

The authors also reported a possible improvement in the disappearance of starch in the total tract of animals fed with HMCS, when compared to those fed dry grain diets, due to the higher digestibility of non-fibrous carbohydrates (NFC).

In the study by Knowlton *et al.* (1999), higher digestibility in the rumen, in the small intestine and total tract of the starch diet, was observed in lactating Holstein cows fed moist grain silage, when compared to a diet composed of dried corn grains. Similarly, Hibberd *et al.* (1985) observed that HMCS showed greater *in vitro* and *in vivo* digestibility, when compared to dry grains.

Tab. 6 contains the mean values of plasma glucose concentrations in the animals.

There was no difference in plasma glucose concentration, with the inclusion of the HMCS in the diet and also for the time x treatment interaction. There was a cubic effect for harvest times (Figure 1).

Table. 6. Replacement effect of dry corn grains for high moisture corn silage (HMCS) on the plasma glucose

	Experimental diets					Average	CV	Effect
	0% HMCS	25% HMCS	50% HMCS	75% HMCS	100% HMCS			
Glucose (mg/dL)	58.36	55.96	56.64	58.60	58.48	57.61	7.27	NS

NS: Not Significant, CV: Coefficient of Variation.

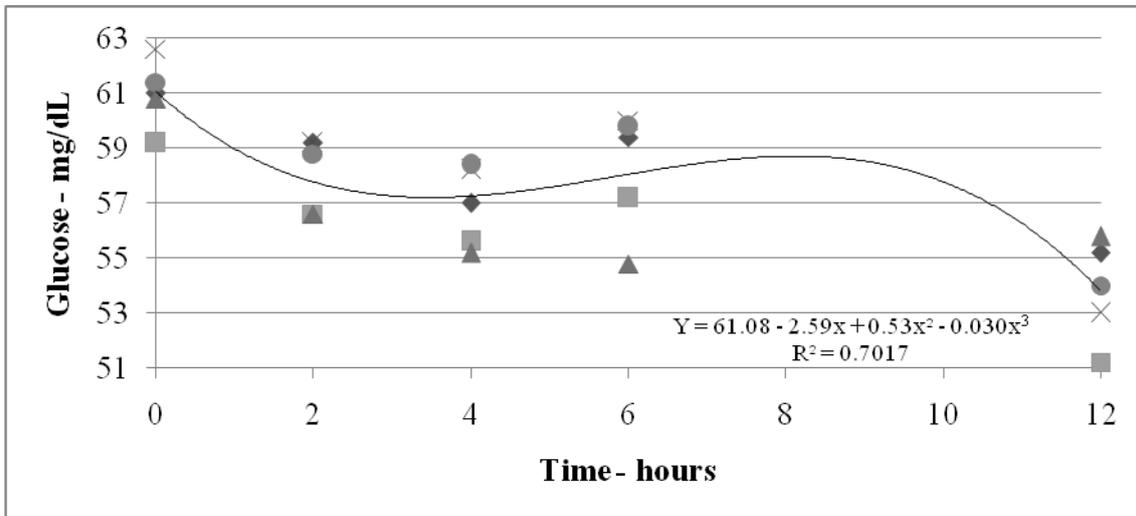


Figure 1. Blood glucose levels, hours after the first meal

Different HMCS proportions in the diet could provide different amounts of glucose, since HMCS has a higher ruminal degradability of starch than ground corn (Owens *et al.*, 1986). It is expected that the high input of soluble carbohydrates in the diet leads to an increase in the propionic acid production, which is the main precursor of glucose in ruminants and, consequently, leading to increased glucose rates.

However, such effect was not observed in this experiment. This effect might not have occurred due to the similar digestible starch intake in the treatments (Tab. 4).

Corroborating with the results obtained in this study, Jorge *et al.* (2002) found no difference in the blood glucose levels with the increased inclusion (0, 25, 50, 75 and 100%) of cassava flour replacing corn in the diet of Holstein calves.

In the results presented by some authors that assessed the processing effect of corn grains on the plasma glucose, no difference was observed in the treatments. Santos *et al.* (2001), assessing coarse ground and flaked corn in the diets of dairy cows, also found no significant difference in the mean values of glucose. The mean

plasmatic glucose value obtained in that study, 56.04mg/gL, is close to that obtained in this study, 57.60mg/gL.

Crocker *et al.* (1998), working with primiparous Holstein cows fed dry-rolled and flaked corn, did not obtain any differences for the different treatments, obtaining 57.9mg/gL as a mean value for the plasmatic glucose concentration. Nussio *et al.* (2002), comparing finely ground corn, coarsely ground or flaked corn in the diet of Holstein cows, found no difference in blood glucose concentrations, obtaining a mean value of 60.30mg/gL.

Macedo Jr *et al.* (2006), analyzing the blood of pregnant sheep, also found differences in the blood glucose levels for the treatment containing 80% concentrate and 20% feed, indicating that the amount of non-structural carbohydrates in the diet can affect the blood sugar levels, which did not occur in this study, where the starch intake quantities were similar.

## CONCLUSION

High moisture corn silage has a higher nutritional value when compared to dry grains in the diets for dairy cows.

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