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Effect of different physical forms of calf starter feed on some rumen parameters

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Abstract

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The aim of the present experiment was to compare the effect of the physical forms of a starter for dairy replacement calves on some rumen fermentation parameters. Nine male calves at 4 days of age and averaging 41.3 (SD = 3.6) kg were divided into three groups. The calves were housed in individual hutches bedded with straw. The calves were weaned at 56 days of age and remained in the experiment until 70 days of age. Three starter feeds of different physical forms were tested: 1) Whole maize grain plus pelleted protein concentrate (WMP); 2) Pelleted starter feed (PSF); and 3) Starter in a meal form with coarsely ground maize (MSF). The ingredient and chemical composition of the three starter feeds were similar. The calves from all groups received 4 L of whole milk until 56 days of age. The liquid feed was provided twice a day from 4 to 35 days of age, and once a day from 36 to 56 days of age. From 35 days of age, calves were offered alfalfa hay ad libitum. Ruminal fluid samples for pH, volatile fatty acids (VFA), ammonia and total number and genera of ciliated protozoa in the ruminal contents were collected using oral stomach tube on days 28, 42, 56 and 70 of the experiment. The results suggested that the physical forms of the starter feed did not affect the pH, VFA and ammonia in the rumen. The total number of ciliated protozoa in the rumen was increased ($P < 0.05$) at 56 and 70 days of age for calves fed the starter feed in PSF form compared to the MSF. The number of ciliated protozoa of the genus *Isotricha* was higher ($P < 0.01$) after feeding with PSF at the age of 28, 42 and 70 days compared with the group fed with MSF diet.

Keywords: calves; starter feed; physical forms; rumen fermentation; protozoa count
Abbreviations: DM – dry matter; CP – crude protein; DDGS – dry distillers' grain with solubles; FUG – feed units for growth; WMP – whole maize grain plus pelleted protein concentrate; PSF – pelleted starter feed; MSF – meal starter feed

Introduction

The intake of solid feed is a major factor for the physical and metabolic development of the rumen (Baldwin et al., 2004; Khan et al., 2007; Khan et al., 2016), allowing for early weaning of calves (Lesmeister and Heinrichs, 2004). A well-developed rumen ensures maximum intake of starter feed and high growth both before and after weaning of calves (Baldwin et al., 2004; Stamey et al., 2012). Ruminal development is strongly influenced by the type and amount of solid feed consumed. Roughages stimulate the development of the rumen muscle layer and maintain a higher pH due to their larger particle size and higher crude fiber content (Kristensen et al., 2007; Pazoki et al., 2017). Although roughage has less influence on the development of rumen papillae, it stimulates rumination and maintains the integrity

and health of the rumen wall (Zitnan et al., 1998). Starter feeds which are typically high in easily fermentable carbohydrates promote early intake (Bateman et al., 2009; Omidi-Mirzaei et al., 2018), and increase the production of VFA in the rumen by stimulating the development of the rumen epithelium (Lesmeister and Heinrichs, 2004).

The processing and physical forms of starter feed affect not only palatability (Terre et al., 2015; Khan et al., 2016), but also rumen fermentation and feed digestibility (Firkins et al., 2001; Hu et al., 2018). Milling and pelleting are the most commonly used methods for processing of the grain feeds during the production of calf starter. Milling reduces the size of feed particles, while pelleting, in addition to improving palatability, reduces screening of ingredients and feed waste (Abdollahi et al., 2018). The reduced size of feed particles during grinding provides better contact with digestive enzymes (Bateman et al., 2009; Lesmeister and Heinrichs, 2004) and the gelatinization of starch during granulation (Bertipaglia et al., 2010) improves starch digestibility. However, excessive grain processing can negatively impact digestibility (Gimeno et al., 2015; Kazemi-Bonchenari et al., 2017), rumen fermentation, and starter intake (Bach et al., 2007). Ground and pelleted starters do not have the necessary particle size to stimulate chewing and rumination. Calves fed ground and pelleted starters begin to ruminate at a later age and survive for a shorter period (Porter et al., 2007). Feeding a milled or pelleted starter high in readily fermentable carbohydrates lowers rumen pH (Ghassemi-Nejad et al., 2012) as a result of increased VFA formation, reduced VFA absorption, and reduced salivary flow (Santini et al., 1983), and increases the risk of acidosis (Beharka et al., 1998). Larger particle size in starter feeds leads to higher rumen pH (Greenwood et al., 1997), likely as a result of longer rumination, which increases the saliva production (Krause and Oetzel, 2006). The effect of particle size on rumen VFA is inconsistent. Some researchers have observed higher VFA concentration at smaller particle size (Beharka et al., 1998; Coverdale et al., 2004), while others, such as Mirzaei et al. (2016), have found that textured starter with larger particle size increases rumen VFA production compared to ground starter. Regarding rumen ammonia concentration, the results obtained are also contradictory. Starter particle size has no effect on ammonia concentration (Suarez-Mena et al. 2016; Du et al. 2021), while fine grinding leads to an increase (Rastgoo et al., 2020) or a decrease (Karkoodi and Khalajzaden, 2014) in ammonia concentration.

The aim of the present experiment was to compare the effect of the physical forms of a starter for dairy replacement calves on some rumen fermentation parameters.

Materials and Methods

Nine male Holstein Friesian calves at 4 days of age and averaging 41.3 (SD = 3.6) kg of BW were divided into three groups. The calves were housed in individual hutches bedded with straw. The calves from all groups received 4 L of whole milk until 56 days of age. The liquid feed was provided twice a day from 4 to 35 days of age, and once a day from 36 to 56 days of age. The calves were weaned at 57 days of age and remained in the experiment until 70 days of age. Three starter feeds of different physical forms were tested: 1) Whole maize grain plus pelleted protein concentrate (WMP); 2) Pelleted starter feed (PSF); and 3) Starter in a meal form with coarsely ground maize (MSF). Grinding of maize was rough with 4 mm sieve in hammer mill and there was no a significant amount of fines. Pellets were medium hard and there were no fine particles in the feeds. The starter feed was pelleted at 4 mm of diameter and 12 mm in length. All starter feeds were offered ad libitum, but the feed refusals were removed every morning and new feed was provided. Ingredients and chemical composition of experimental starters are shown in Table 1. From 35 days of age, calves were offered alfalfa hay ad libitum. Clean water was offered in a bucket from the 4th day of age, and was replaced with fresh water every morning. Ruminal fluid samples for pH, volatile fatty acids (VFA), ammonia and total number and genera of ciliated protozoa in the ruminal contents were collected using oral stomach tube on days 28, 42, 56 and 70 of the experiment.

On days 28, 42, 56 and at the end of the experiment (d 70), 3 h after the morning feeding, rumen fluid was sampled using a stomach tube. Rumen pH was measured immediately using a hand-held pH meter (HI 8314 membrane pH meter, Hanna Instruments, Villafranca, Italy). An aliquot (4 mL) of rumen fluid was acidified with 1 mL of 25% metaphosphoric acid and stored (-20 °C) until analysis for volatile fatty acids (VFA) by gas chromatography (0.25 × 0.32, 0.3 mm id fused silica capillary, model no. CP- 9002 Vulcanusweg 259 am, Chrompack, Delft, The Netherlands) (Kargar et al., 2012).

Feeds were analyzed by wet chemistry methods for DM, crude protein, crude fiber, ether extract, calcium and phosphorus as described by AOAC International (2007).

The results were statistically processed using STATISTICA 10 for Windows (2010). Significance was declared at $P < 0.05$.

Results and Discussion

The results suggested that the physical forms of the starter feed did not affect the pH, VFA and ammonia in the rumen (Table 2).

The pH level of the rumen is determined by the amount of VFA formed, the absorption of these acids, the buffering capacity and outflow of acids from the rumen. The size and processing of grain feeds affect the rate of starch fermentation in the rumen (Suarez-Mena et al., 2016). Larger particle size in the starter determines a higher pH (Greenwood et al., 1997), likely due to slower rates of rumen fermentation and increased saliva production as a result of longer rumination in calves (Krause and Oetzel, 2006). Finely ground starters, especially those high in rapidly fermentable carbohydrates, lower rumen pH (Ghassemi-Nejad et al., 2012) due to the higher rate of fermentation. Lesmeister and Heinrichs (2004) found that calves fed whole corn starters had higher pH than those fed processed corn. Porter et al. (2007) also observed higher rumen pH at 8 weeks of age in calves fed a textured starter compared to a pelleted starter. We found no differenc-

Table 1. Composition and nutritional value of dietary treatments

Items	WMP*	PSF*	MSF*
Ingredients	%	%	%
Maize, different form	50.0	50.0	50.0
Protein concentrate	50.0		
Sunflower meal	10.0**	10.0	10.0
DDGS from maize	20.0**	20.0	20.0
Canola meal	18.55**	18.55	18.55
Limestone	1.2**	1.2	1.2
TMV premix***	0.25**	0.25	0.25
Total	100.0	100.0	100.0
Energy and nutrients in 1 kg			
Dry mater, g	858	860	876
FUG	1.27	1.28	1.30
Crude protein, g	195	195	199
Crude fiber, g	66.3	66.5	67.7
Ether extracts, g	38.8	38.9	39.6
Calcium, g	6.39	6.40	6.52
Phosphorus, g	5.35	5.36	5.46

*WMP – whole maize plus pelleted protein concentrate, PSF – pelleted starter feed, MSF – starter in meal form with coarsely grounded maize
**As a component of pelleted protein concentrate
***Trace mineral-vitamin premix
Source: Authors' own elaboration

Table 2. Effects of different physical forms of starter on rumen fermentation parameters

Items	WMP*		PSF*		MSF*	
	x	±Sx	x	±Sx	x	±Sx
Ruminal pH						
day 28	5.73	0.26	6.01	0.17	5.42	0.13
day 42	5.81	0.36	5.84	0.26	6.51	0.06
day 56	6.00	0.04	5.47	0.27	5.63	0.16
day 70	6.41	0.20	5.89	0.14	6.22	0.07
VFA, mmol/l						
day 28	53.33	1.67	56.25	1.25	53.75	1.25
day 42	62.92[a]	2.32	76.67	15.85	74.75[b]	0.95
day 56	66.25	1.25	70.00	1.25	74.58	2.92
day 70	68.33	1.82	64.82	1.16	65.83	5.42
Ruminal NH_3, mg%						
day 28	14.03	2.63	13.61	0.46	13.60	3.15
day 42	11.22	0.30	12.74	1.84	11.21	0.89
day 56	8.61[a]	0.11	8.33[a]	0.16	8.08[b]	1.04
day 70	8.05	0.36	8.47	0.15	8.00	1.02

a,b,c – Different superscripts within a row indicate significant difference ($P < 0.05$).
Source: Authors' own elaboration

es in rumen pH (P > 0.05) before and after weaning (Table 2), although there was a tendency toward higher pH values at 56 and 70 days in the WMP group. Kazemi-Bonchenari et al. (2017), Pazoki et al. (2017), Du et al. (2021), and Gholizadeh et al. (2021) also did not observe an effect of starter physical forms on rumen pH.

The level of VFA determines the pH values in the rumen. According to Nagaraja and Titgemeyer (2007), a VFA concentration above 150 mmol/L has the potential to strongly reduce the pH of the rumen and shift the fermentation towards the formation of more lactate (Gimeno et al., 2015). Terre et al. (2013) found a high correlation between VFA concentration and rumen pH at pH > 5.1, but not at pH < 5.1, suggesting that other factors, such as increased lactic acid production, also influence rumen pH. The effect of physical forms, which determines starter particle size, on rumen VFA is inconsistent. Some researchers have observed higher VFA concentrations in starters with smaller particle sizes (Beharka et al., 1998; Coverdale et al., 2004), which is likely due to higher rumen starch digestibility (Theurer et al., 1999; Gimeno et al., 2015), while others have observed higher VFA levels in starters with larger particle sizes (Mirzaei et al., 2016). However, many studies have not found such a difference (Suarez-Mena et al., 2015; Du et al., 2021; Gholizadeh et al., 2021). Our data also showed no differences in rumen VFA concentration (P > 0.05) on days 28, 56 and 70, with significantly higher VFA concentration in the MSF group compared to WMP on day 42 (P < 0.05). Although the amount of VFA formed increases with age due to the increase in starter intake, at 70 days of age we observed lower VFA values at a higher pH compared to 56th day in the WMP and MSF groups, which is likely due to the development of more mature rumen epithelium capable of absorbing more VFA or a faster rumen turnover rate (Suarez-Mena et al., 2015).

The concentration of ammonia (NH3) in the rumen decreases with age, mainly as a result of its increased utilization by the microbial population (Beharka et al., 1998; Lesmeister and Heinrichs, 2004). It also depends to some extent on pH values, since according to Bach et al. (2005) protein degradation decreases when pH is below 5.5. The composition of the diet also determines the NH3 values in the rumen. The presence of more readily available carbohydrates determines the higher level of NH3 utilization in the rumen. We also found a decrease in the amount of NH3 in the rumen with increasing age of the calves. The NH3 values at 28, 42 and 56 days of age did not show differences between the groups depending on the physical forms of the diet. Suarez-Mena et al. (2015) and Du et al. (2021) also found no differences depending on the physical forms of the starter, while others observed lower values in ground and pelleted starters (Beharka et al., 1998; Pazoki et al., 2017), in which

Table 3. Effects of different physical forms of starter on protozoal counts

Items	WMP*		PSF*		MSF*	
	x	**±Sx**	x	**±Sx**	x	±Sx
Total number of ciliated protozoal (10^3/cm^3)						
day 28	16.67	1.54	11.83	4.71	14.17	1.87
day 42	18.00	1.06	15.67	1.05	16.00	2.18
day 56	23.83^a	2.88	40.83^b	3.56	26.33^a	2.17
day 70	32.33^a	2.49	77.83^b	5.41	18.83^c	1.17
Entodinium (%)						
day 28	99.33	0.33	65.67	20.77	91.50	3.03
day 42	99.33	0.33	98.50	0.43	96.50	1.59
day 56	99.33	0.33	98.67	0.49	98.33	0.33
day 70	98.50^a	0.43	93.50^b	1.34	96.83^c	0.60
Diplodinium (%)						
day 28	0.67^a	0.33	1.00^{ab}	0.52	8.50^c	3.03
day 42	0.67	0.33	1.50	0.43	3.50	1.59
day 56	0.67	0.33	1.33	0.49	1.67	0.33
day 70	1.50^a	0.43	5.50^b	0.62	3.17^c	0.60
Isotricha (%)						
day 28	0	0	0.83	0.31	0	0
day 42	0	0	3.33	0.99	0	0
day 56	0	0	3.00	1.30	0	0
day 70	0	0	3.00	0.73	0	0

a,b,c – Different superscripts within a row indicate significant difference (P < 0.05).
Source: Authors' own elaboration

the digestibility of starch in the rumen was higher (Theurer et al., 1999; Gimeno et al., 2015). Higher NH3 values in a starter feed with ground corn compared to flaked corn were found by Rastgoo et al. (2020), which is likely due to better nitrogen utilization when calves were fed flaked rather than ground corn grain.

Under the conditions of this study, the physical forms of the starter feed had no effect on the fermentation processes in the rumen.

The total number of ciliated protozoa in the rumen was increased ($P < 0.05$) at 56 and 70 days of age for calves fed the starter feed in PSF form compared to the MSF (Table 3). The number of ciliated protozoa of the genus *Isotricha* was higher ($P < 0.01$) after feeding with PSF at the age of 28, 42 and 70 days compared with the group fed with MSF diet. Within the rumen, the number of *Isotricha* can change significantly based on the diet composition (Francisco et al., 2019).

Conclusion

Overall, in the present experiment the physical forms of a starter feed for dairy replacement calves did not affect some rumen fermentation parameters including the pH, VFA and ammonia. However, the total number of ciliated protozoa in the rumen was increased ($P < 0.05$) at 56 and 70 days of age for calves fed the starter feed in PSF form compared to the MSF. The number of ciliated protozoa of the genus *Isotricha* was higher ($P < 0.01$) after feeding with PSF at the age of 28, 42 and 70 days compared with the group fed with MSF diet.

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