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Nutrition and Physiology

Effect of physical form of starter feed on nutrient digestibility of dairy calves

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Abstract. *The present experiment aimed to compare the effect of the physical form of a starter for dairy replacement calves on some rumen fermentation parameters. Nine male calves 4 days old and averaging 41.3 kg (SD = 3.6) were divided into three groups. The calves were housed in individual hutches bedded with straw. The calves were weaned at the age of 56 days of age and remained in the experiment until they reached 70 days. Three different physical forms of starter feeds were tested: 1) Ground starter – starter in meal form with coarsely ground maize (GS); 2) Pelleted starter (PS); and 3) Textured starter – a mixture of whole maize grain plus pelleted protein concentrate (TS). The ingredients 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 daily from 4 to 35 days of age, and once daily from 36 to 56 days. From 35 days of age, calves were offered a free choice of alfalfa hay. OM digestibility was lower in calves that received ground starter compared to calves fed pelleted starter and textured starter. Apparent total tract digestibility of CP was the lowest in calves fed GS compared to those receiving PS and TS (P <0.05). No statistically significant difference in CP digestibility was observed between PS and TS-fed calves. EE digestibility was significantly lower in calves that received GS compared to those that received PS (P <0.05), but not different from EE digestibility in calves fed TS. The highest EE digestibility was that in PS-fed calves. CF digestibility was the highest in calves that received PS and the lowest in those fed GS, with significant differences (P <0.05). There was no significant difference in NFE digestibility among tested physical forms of starter feeds.*

Keywords: calves, starter feed, physical form, nutrient digestibility
Abbreviations: CF – crude fiber, CP – crude protein, DDGS – dry distillers grain with solubles, DM – dry matter, EE – ether extract, FUG – feed units for growth, GS – ground starter, NFE – nitrogen free extract, PS – pelleted starter, TS – textured starter

Introduction

The most popular methods of feed processing, which alter the physical form of the diet, particularly its coarseness, degradability, and nutrient digestibility, include grinding, mixing and pelleting (Karimizadeh et al., 2017). Ground starter, pelleted starter and texturised starter feeds are used in rations of calves (Bateman et al., 2009; Pazoki et al., 2017). Texturised starter feeds contain either processed or whole cereal feeds with various proportions of grain and pellets. Cereals have different fermentation properties. The slower fermentation of maize and oat compared to that of wheat and barley may increase the amount of starch in the reticulorumen environment (Khan et al., 2007). It may pose a problem for starch digestibility in the small intestine because of the low production of pancreatic α-amylase before weaning (Dennis et al., 2017). The reduced size of feed particles after grinding results in better contact with digestive enzymes (Lesmeister and Heinrichs, 2004; Bateman et al., 2009) and starch gelatinisation during pelleting (Bertipaglia et al., 2010; Ebrahimi, 2020) can improve starch digestibility (Huntington, 1997; Owens et al., 1997). Feeding ground or pelleted starters, high in easily fermentable carbohydrates, may decrease ruminal pH (Ghassemi-Nejad et al., 2012) and increase the risk from acidosis (Ebrahimi, 2020) resulting from formation

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of more VFA, reduced VFA absorption and lower salivary flow (Santini et al., 1983). A larger particle size in starter feeds is associated with a higher ruminal pH (Greenwood et al., 1997), most probably due to the prolonged rumination increasing saliva production (Krause and Oetzel, 2006). However, the excessive processing of cereals may have a negative impact on both starter feed intake (Bach et al., 2007; Omidi-Mirzaei et al., 2018), and nutrient digestibility (Gimeno et al., 2015; Kazemi-Bonchenari et al., 2017). The presence of the high amount of fine particles in the starter decreases the time of their retention in the rumen and thus, leads to lower digestibility of nutrients (Porter et al., 2007; Ghorbani et al., 2020). This may explain the reduced digestibility of nutrients in calves fed ground starter feeds. Numerous studies have demonstrated the effects of various feed processing methods and physical forms of starter on nutrient digestibility in calves, both prior to and after weaning (van Niekerk et al., 2020; Makizadeh et al., 2020; Rahimi et al., 2023). Porter et al. (2007) found higher digestibility of DM, EE, NFE and NDF in calves receiving coarse mash starter compared to those receiving pelleted starter. According to Pazoki et al. (2017), there was a small difference in DM, OM and CP digestibility in calves fed pelleted starter and textured starter, yet it was higher than the digestibility in calves fed ground starter. However, Ghassemi-Nejad et al. (2012) found no difference in the digestibility of DM, CP, ADF and NDF between calves fed either pelleted starter or textured starter, whereas calves fed diets with ground starter exhibited constantly lower DM, OM and CP digestibility. Not only does the physical form of the starter influence nutrient digestibility, but the age of the calves also plays a significant role. Calves that received textured starter showed increased digestibility or a tendency toward increased digestibility of DM, OM, starch and sugar at 6 weeks of age, as well as of NDF, ADF and CP at 8 weeks of age compared to calves fed pelleted starter. However, at 13 weeks of age the digestibility of DM, OM, starch, NDF, ADF and fats was lower in calves fed textured starter (Quigley et al., 2019).

The aim of the present experiment was to compare the effect of the physical form of a starter for dairy calves on nutrient digestibility.

Material and methods

The animal experiment was conducted in the Research Center at the Faculty of Agriculture, Trakia University. Nine male calves of the Black and White breed, 4 days old and averaging 41.3 kg (SD = 3.6), were divided into three groups. The calves were each housed in individual straw-bedded hutches. 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) Ground starter – a meal-form starter with coarsely ground maize (GS); 2) Pelleted starter (PS); and 3) Textured starter – a mixture of whole maize grain plus pelleted protein concentrate (TS). The maize was coarsely ground using a 4 mm sieve in the hammer mill, resulting in a minimal amount of fine particles. Pellets were medium hard and there were no fine particles in the feeds. The starter feed was pelleted at 4 mm in diameter and 12 mm in length. All starter feeds were offered ad libitum, but the remaining feed was removed every morning and a new feed was provided. The ingredients and chemical composition of the experimental starters are shown in Table 1.

Table 1. Composition and nutritional value of dietary treatments

Items	GS*	PS*	TS*
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 starter			
Dry matter, g	876	860	858
Crude protein, g	199	195	195
Crude fiber, g	67.7	66.5	66.3
Ether extract, g	39.6	38.9	38.8
Calcium, g	6.52	6.40	6.39
Phosphorus, g	5.46	5.36	5.35

* GS - ground starter, PS - pelleted starter, TS - textured starter
** As component of pelleted protein concentrate
*** Trace mineral-vitamin premix

From 35 days of age, calves were offered a free choice of alfalfa hay. After weaning at 57 days of age calves were moved to individual metabolic cages to conduct digestibility trials. The experiment comprised a 7-day adaptation period and a 7-day collection period, during which faeces were gathered. During the adaptation period, the animals were fed *ad libitum* to determine feed intake. After the end of the adaptation period, the necessary amount of feed was weighed for each day of the **collection period**. Calves had access to fresh tap water and were fed twice daily: at 08.30 h and 16.30 h. The remaining feed was collected every morning before feeding and stored in individual nylon bags. To determine the digestibility of nutrients, chromic oxide (Cr_2O_3) in gelatin capsules was used as an external marker. It was administered in the morning before the feeding (6 g/calf/day) through an oesophageal probe from the beginning of the adaptation period.

The collection of faeces during the collection period was done in the morning, before feeding the animals. Faecal samples were dried in a dryer at 65°C, then were ground through a 1-mm sieve and sealed in plastic bags for further analysis.

DM, crude protein, crude fiber, ether extract, calcium and phosphorus in feeds were determined according to the methods described by AOAC International (2007).

The sample for mineral content analysis was obtained after dry ashing (BSS ISO 5984), and treated with 6n HCl. Chromium content was determined using an atomic absorption spectrophotometer Perkin Elmer, ANALYST 800 AA SPEKTROMETER, at 357.9 nm

Digestion coefficient of nutrients was calculated according to the formula:

KC = 1- (Indicator in feed X Nutrient in faeces / Indicator in faeces X Nutrient in feed)

Statistical analysis was performed using STATISTICA 10 for Windows (2010). Significance was declared at $P<0.05$.

Results and discussion

The results for the nutrient digestibility are shown in Table 2. The data demonstrate statistically significant differences in most studied parameters.

Table 2. Apparent digestibility of calf starter diets

% digestibility	GS*		PS*		TS*	
	x	St Dev	x	St Dev	x	St Dev
OM	**77**^{a}	2.98	**80**^{ab}	6.74	**82**^{b}	5.76
CP	**68**^{a}	4.38	**75**^{b}	7.69	**79**^{b}	6.78
EE	**78**^{a}	7.30	**83**^{b}	8.32	**78**^{a}	5.30
CF	**51**^{a}	5.99	**68**^{b}	10.82	**73**^{c}	5.01
NFE	**84**	2.70	**85**	5.94	**84**	5.85

* GS - ground starter, PS - pelleted starter, TS - textured starter

a,b,c – Means within a row lacking a common superscript differ significantly at $P < 0.05$.

OM digestibility was lower in calves fed ground starter compared to either pelleted or textured starter. These results align with the data reported by Ghassemi-Nejad et al. (2012) and Pazoki et al., (2017). Quigley et al. (2019) also observed a tendency towards increased OM digestibility in 8-week-old calves that received textured starter vs pelleted starter.

Apparent total tract digestibility of CP was the lowest in calves fed ground starter compared to animals on pelleted starter ($P <0.05$) and textured starter rations. The digestibility of CP did not differ statistically significantly between calves that received pelleted starter or textured starter. Our results agreed with those of Ghassemi-Nejad et al. (2012) reporting a lower CP digestibility of calves fed ground starter, but without significant difference between calves fed pelleted starter and textured starter. Similar data were published by Pazoki et al. (2017) in a study that evaluated the digestibility of ground starter, textured starter and pelleted starter feed. The authors reported lower CP digestibility ($P<0.01$) in calves on ground starter ration compared to those fed pelleted starter, but the difference in digestibility between ground starter and textured starter rations was not significant. However, according to Quigley et al. (2019), the digestibility of CP in calves fed textured starter exceeded that in calves fed pelleted starter at 6 and 8 weeks of age. Higher CP digestibility in calves maintained on pelleted starter versus textured starter was observed by Du et al. (2021).

EE digestibility was lower in calves that received ground starter compared to pelleted starter ($P<0.05$), yet was not different from the EE digestibility in calves fed textured starter. The highest EE digestibility was

observed in calves fed pelleted starter. However, Porter et al. (2007) established higher EE digestibility in animals fed coarse mash starter in comparison to pelleted starter. The reported results of other research teams on EE digestibility of pelleted starter and textured starter were inconsistent. Thus, Quigley et al. (2019) demonstrated higher EE digestibility in calves fed textured starter at 8 weeks of age, whereas Du et al. (2021) reported higher EE digestibility for the pelleted starter ration.

The CF digestibility was statistically significantly higher in calves that received textured starter, and the lowest – in animals fed ground starter ($P<0.05$). Similarly, Quigley et al. (2019) reported higher NDF and ADF digestibility in calves fed textured starter compared to those on pelleted starter. The lower CF digestibility in calves fed ground starter may be attributed to the lower retention time in the rumen and the faster passage of nutrients through the digestive tract (Ghorbani et al., 2020). Conversely, Porter et al. (2007) demonstrated higher CF digestibility for coarse mash starter ration compared to pelleted starter. Ghassemi-Nejad et al. (2012) observed lower NDF and ADF digestibility in pelleted starter and textured starter vs the ground starter and presumed that this was due to the higher DMI of pelleted and textured starters. However, our study found no difference in feed intake in calves fed starter rations with the same composition and physical form (Yavuz et al., 2015). Du et al. (2021) determined higher digestibility of NDF and ADF for pelleted starter compared to textured starter and suggested that this may be due to the very hard corn that reduced textured starter digestibility.

Our results did not provide proof of any considerable difference in NFE digestibility in connection to the starter physical form. However, this was not the case with the data reported by Porter et al. (2007) about higher NFE digestibility in calves that received coarse mash starter in comparison to calves fed pelleted starter.

Solid feed intake from the first day of life increases solid feed intake and can positively affect the development of rumen microflora, rumen fermentation as well as its epithelium. Solid feed, especially concentrate or high carbohydrate diets, stimulate rumen microbial proliferation and volatile fatty acid production, which initiate rumen development (Govil et al., 2017).

During the fermentation of starter feeds in the rumen, greater amounts of propionate and butyrate are formed, whereas during the fermentation of feeds with high fibre content – the acetate amount is increased (Khan et al., 2016). Butyrate and propionate are beneficial for the development of rumen papillae. A well-developed rumen ensures a maximum intake of starter feed and a high weight gain both before and after weaning of calves (Baldwin et al., 2004; Stamey et al., 2012).

The physical form and size of feed particles also have a substantial effect on the anatomical and microbial development of the rumen (Beharka et al., 1998, Pazoki et al., 2017). Calves fed ground feed demonstrate shorter papillae with smaller surface areas than calves fed non-ground feed. In them, a reduction of cellulolytic bacteria and more numerous amylolytic bacteria (Beharka et al., 1998), as well as decreased ruminal pH (Laarman and Oba, 2011) are observed.

In calf nutrition, ground starter, pelleted starter and textured starter feeds are used (Bateman et al., 2009; Pazoki et al., 2017). Texturised starter feeds contain processed or whole cereals with various proportions of grain and pellets.

Some authors (Porter et al., 2007; Quigley et al., 2018; Du et al., 2021) affirmed that the digestibility of nutrients may be influenced by the physical form of the diet, whereas others (Coverdale et al., 2004; Bach et al., 2007; Nejad et al., 2012) reported no effect of pelleted versus texturised starter on digestion or growth. Despite that, processed starter feeds are supposedly more digestible than non-processed ones, it appears that the digestibility of texturised and pelleted starter feeds depends also on the age of the calves (Quigley et al., 2019).

The presence of a large amount of fine particles in calf starter feeds reduces the retention time in the rumen, leading to a faster passage of nutrients through the digestive tract and lower nutrient digestibility (Ghorbani et al., 2020). This can explain the lower digestibility of nutrients in calves fed ground starter. Furthermore, ground rations can result in lower ruminal pH, reduced cellulolytic bacterial counts, and potentially, malformation of rumen papillae (Beharka et al., 1998). Even though pelleting of starter feeds improves the palatability and decreases the segregation of ingredients, pelleted starter feeds may influence rumen fermentation as lower particle size decreases digestibility (Wilkins et al., 1972) and may have an adverse effect on feed intake (Bach et al., 2007). Whole grains in textured feeds may be more effective in supporting rumen health and animal performance compared with highly processed grains (Terré et al., 2015).

Conclusion

OM digestibility was lower in calves fed ground starter compared to those that received pelleted starter and textured starter. Apparent total tract digestibility of CP was the lowest in calves fed GS compared to those on PS and TS rations ($P<0.05$). No statistically significant

difference in CP digestibility has been observed between PS and TS-fed calves. The EE digestibility was lower in calves that received GS vs PS (P<0.05), but not different from EE digestibility in calves fed TS. The highest EE digestibility was that in PS-fed calves. CF digestibility was the highest in calves that received PS, whereas the lowest one was found in GS-fed animals with relevant differences (P<0.05). There was no significant difference in NFE digestibility among tested physical forms of starter feeds.

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