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Effect of physical form and protein source of starter feed on growth and development of dairy calves

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Abstract. The objective of this paper was to review the literature on effects of different methods of processing of grain fraction of the starter feeds for young dairy calves, as well as providing another part of starter which is a source of protein, minerals and vitamins in different physical forms. The second aim was to discuss the impact of the main protein sources for starter feeds on performance of preweaning and postweaning dairy calves. The main criteria for assessment of physical form effect and sources of protein in the starter feeds were intake of dry feeds, daily live weight gain and frame size growth of calves, morphological and functional development of forestomachs, digestibility of feeds and health status of young calves. Data show big variations and lack of consistency of experimental results. Good results were achieved when calves were fed whole, ground, dry-rolled, pelleted and steam-flaked grains. It seemed that fineness of grinding and quantities of fine fraction were important for starter intake. Steam-flaking and grinding improved digestibility to the same extent, but whole grain stimulated chewing and improved rumen environment for bacteria growth. Soybean meal was the most palatable and ensured best performance of calves.

Evidently, it is possible to replace soybean meal with rape seed, canola type meal, dry distillers grain with solubles (DDGS) and other protein sources which contain more fiber and are less digestible. However, it is difficult to appraise how much and at what conditions is it possible to replace completely or a maximum possible portion of soybean meal. Additional studies are needed to clarify interactions between physical form of starters, rumen fermentation environments and age of calves. Information for composition of diets is needed allowing inclusion of maximum amounts of canola meal, DDGS and sunflower meal, which are produced locally and are cheaper than soybean meal, without decreasing live weight gain and development of dairy calves.

Keywords: calf, starter feed, protein source, flaking, dry rolling, grinding, fine particles, pelleting, whole grain


Introduction

Growth, health and performance of calves depend on many environmental, management and feeding factors. This short review is dealing only with the effect of physical forms and protein sources of starter feed for calves of dairy breeds, pre-weaning and during the first month after weaning. The paper does not discuss the effects of quantity and quality of liquid feeds as natural milk, non marketable milk and different milk replacers, as well as other nutritional factors of calf development as supplements to improve palatability, taste etc. Intake of dry feeds (starters) is connected with morphological and functional development of rumen and to a lesser extent, to the whole digestive tract of calves. Intake of starters from young calves depends first of all on the quantity of consumed milk or milk replacer, but also on composition, palatability and physical form of starter feeds (Fokkink et al., 2010; Pezhvah et al., 2014). Solid feed, especially concentrate or high carbohydrate diets, stimulates rumen microbial proliferation and volatile fatty acid production, which initiate rumen development (Baldwin et al., 2004; Kehoe et al., 2007). As the rumen develops, calves are able to consume more starter and forages and can be weaned early. The effect of physical forms of starter is important because it is closely connected with the price of starters.

The protein sources in starter feeds are also important for the growth and development of calves. Soybean meal (SBM) is one of the most commonly used protein sources in calf starters (Davis and Drackley, 1998; Miller-Cushon et al., 2014), because calves prefer soybean meal over sunflower meal, dry distillers grain with solubles (DDGS) or canola meal (Montoro et al., 2010; Miller-Cushon et al., 2014; Miller-Cushon et al., 2014a). However, sunflower meal, DDGS, and canola meal are available in the Balkan area and are significantly cheaper compared to imported soybean meal. Therefore it is important to know whether it is possible to replace soybean meal with local protein sources.

The objective of this paper was to review published literature concerning needs to apply expensive grain processing for young calves and the possibility to replace partly or completely soybean meal with available local protein sources without compromising the health and development of dairy calves before weaning and immediately after weaning.

Effect of dry feeds on rumen development in calves

Liquid feeds, such as milk or milk replacer, are the main diet for newborn calves. Because the milk surrounds the rumen through the esophageal groove, it does not stimulate the development and metabolic activity of the rumen (Heinrichs and Lesmeister, 2005). Though with the age the calf may have an increase in rumen size, the rumen function will still be underdeveloped when only milk or milk replacer are fed.

Solid feeds promote microbial proliferation within the rumen, yielding volatile fatty acids (VFA), which enhance rumen
development. Physical properties of the calf starter are considered influential in promoting such histological shifts and maturity of the rumen papillae. This cascade is sustained by a capacious absorption and modification of VFA across the rumen to fuel the intermediary metabolism (Baldwin et al., 2004). Solid feeds have also been reported to promote papillary development. Solid feeds can consist of concentrates and/or forages. Though both concentrates and forages have been linked to rumen stimulation, it is clear that concentrates have the greatest effect on rumen development.

Heinrichs and Lesmeister (2005) established that feeding concentrates can cause an increase in papillae length and improve the thickness of the rumen wall. The improved development of both the papillae and rumen wall will cause an increase in surface area, improving the absorption of nutrients. Feeding concentrates will create the proper environment for rumen microbes development. This will allow the microbes to produce butyrate which in turn will cause even greater rumen development. Although much attention is paid on feeding concentrates to young ruminants, the importance of forages for rumen development should be remembered. Coverdale et al. (2004), Hill et al. (2009) reported that early weaned calves fed forages consumed more feed and had improved weight gains. The increase in feed intake has been shown to lead to an increase in VFA concentrations (Coverdale et al., 2004). Both particle size and bulk content will stimulate rumen contractions, which accelerates passage of feedstuffs from the rumen into the intestines (Heinrichs and Lesmeister, 2005).

Ration particle size influences ruminal environment, VFA production, and papillae structure and function. Chopped or ground to fine particle size diets decrease rumen pH and cellulolytic bacteria populations (Beharka et al., 1998). Moreover ruminal papillae of animals receiving small forage particles have increased keratinization. This decrease in active tissue leads to decreased VFA absorption (Greenwood et al., 1997b). This could induce post-ingestive negative effects reducing consumption in the long run. Providing chopped diets or forage increases chewing activity, and consequently increases ruminal pH, and helps to maintain the integrity and healthiness of the rumen wall (Krause et al., 2002; Yansari et al., 2004).

**Importance of starter feed intake**

A gradual transition from liquid to solid feed is important for minimizing weight loss and distress at weaning (Weary et al., 2009). There are a number of factors that affect starter dry matter intake (DMI). Quigley (1996) proposed a DMI predicting equation that included calf age, body weight (BW), live weight gain (LWG), milk DMI and calf gender. Nonetheless, many other factors such as hay availability, incidence and severity of diarrheas, method of milk feeding, and environmental temperature may also be used to predict DMI (Quigley, 1996). The most important factors influencing the early intake of the starter are palatability and texture. However, nutritional value and digestibility are also important (Davis and Drackley, 1998).

Calves start consuming small amounts of solid feed at about 14 days of age (Williams and Frost, 1992; Khan et al., 2008). Yavuz et al. (2015) find a big individual variation in beginning to eat dry feed. At low milk intake calves start to consume some dry starter at 6 days of age. Intake of solid feed increases quickly when milk rations are reduced (Khan et al., 2007a,b) or calves are weaned (Jasper and Weary, 2002). The relationship between milk and solid feed intake has been demonstrated in many researches (Terré et al., 2007; Raeth-Knight et al., 2009, Khan et al., 2011). Calves fed liquid feed to 10% of BW consume nearly twice as much starter as calves fed higher amounts in the weeks before weaning (Jasper and Weary, 2002; Cowles et al., 2006; Raeth-Knight et al., 2009). By the fourth week of life, calves should consume more nutrients from calf starter than from milk or milk replacer, which increases the importance of feeding a nutritious, highly palatable starter (O’Brien et al., 2004).

Ingredients with high content of carbohydrates are the main source of energy. Corn, wheat, barley, oat and sorghum are commonly used as carbohydrates sources in animal feeds (Huntington, 1997). The physical form of starch and the cellular integrity of starch-containing units, affect the nutrient digestibility and grain availability to the microbes. Wheat, barley, oats are more rapidly fermented than corn and sorghum (Huntington, 1997) because the distribution of starch granules within the kernel varies with cereal type (Kotarski et al., 1992; Swan et al., 2008). The ratio of amylose:amylopectin also varies in cereal grains and is negatively correlated with starch digestion (Svihus et al., 2005). The most commonly used grain in calf starters is corn because of the nearer to ideal rate of breakdown in the rumen and its high digestibility (Davis and Drackley, 1998). Maiga et al. (1994) found that corn gave the best live weight gains. In a study (Lesmeister and Heinrichs, 2004), roast-rolled corn was reported as the type of processed corn that showed the best ability for conversion of ingested nutrient into growth and that prepared the calves rumen for weaning.

Apart of cereal grains, other ingredients are also used as carbohydrates source, for example cane or sugar beet molasses. Calf starters commonly contain approximately 5 to 12% liquid molasses to increase palatability, minimize particle separation, and decrease dust (Morales et al., 1989). However, a high concentration of molasses (12 vs. 6 %) has been shown to decrease DMI, may possibly induce palatability problems, reduce average daily gain (ADG) and increase the incidence of scours in calves (Lesmeister and Heinrichs, 2005).

The starter should have a relatively high content of readily fermentable carbohydrates, but adequate digestible fiber content to support the fermentation necessary for proper ruminal tissue growth (Greenwood et al., 1997b). The fiber source also influences solid feed intake. Diets rich in fiber (Porter et al., 2007; Zanton and Heinrichs, 2009) and high DMI (Zanton and Heinrichs, 2008) decrease diet digestibility. Porter et al. (2007) established that dry matter (DM) digestibility in animals fed high-fiber diets (27% NDF) was lower than calves fed low-fiber diets (20% NDF). Castells et al. (2012) reported that providing chopped oat hay, chopped barley straw, or triticale silage ad libitum with concentrate starter improves solid feed consumption and ADG compared calves that have not received forage. However, these benefits were not observed when alfalfa hay was chopped.

To improve energy intake, calf starter may be supplemented with fat sources. Supplemental fat ingredients in order to increase the energy content are mostly free fats, like hydrolyzed animal fat (Luchini et al., 1993). However, the inclusion of 7.3% fat in the starter decreased starter intake after weaning, and did not improve ADG (Kuehn et al., 1994). Stewart and Schingoethe (1984) fed calves starters with 6.3% and Luchini et al. (1993) 5.8% fat, however, the animals did not benefit from the supplemental fat compared with calves fed 2.2 or 1.7% fat starter, respectively. In general, starters above 5% fat generally result in depression of DMI, which negates the potential of increased energy density to improve energy intake (Davis and Drackley, 1998). O’Brien et al. (2004) reported a greater average daily gain, higher feed intakes from week 3 through the end of the trial (at least 42 days of age), earlier weaning age and greater...
average weekly weights for calves fed a 18% protein, 5% fat starter than calves fed starter with 18% protein and 3% fat.

The effect of physical form of starter feed

Many methods of processing grains are applied with different changes of grain structure, fermentation into rumen and digestibility of feeds (Table 1). Dry rolling and grinding decreased size of particles and produced fine particles. Other methods affect rumen fermentation and digestibility by changing the structure of grain starch granule. Calves generally do not like fine ground (meal) feeds, and palatability and intake are usually lower than other types of feeds. A long time ago Lassiter et al. (1955) found that calves consume more pelleted starter, compared to meal starter feed. Recently textured calf starters with corn flakles and pelleted supplements became popular, due to their increased volume and palatability compared to meal and pelleted starters (Franklin et al., 2003; Ghasssemi Nejad et al., 2012). Some researchers also used successfully whole corn grains plus pelleted protein concentrate (Chester-Jones et al., 1991; Owens et al., 1997; Bateman II et al., 2009; Terré et al., 2015). Feeding texturized starter consisting of whole grains and pelleted protein concentrate ensured good LWG and rumen papillae development of calves (Fokkink et al., 2010). Surprisingly, in some trials with feedlot cattle, starch digestibility and net energy value were greater for whole than for rolled grains (Owens et al., 1997). This may be attributed to longer ruminal retention time for whole than rolled corn. Better daily gain of calves fed whole maize grain compared to processed grain was repotted also by Lesmeister (2003).

Steam-flaking maize is the most effective method for improving digestibility and utilization of starch, but this processing method is the most expensive. Several authors have mentioned 6 to 10% improvement in utilization of starch in trials with growing cattle. In small calves, during the milk feeding period, especially when they were receiving only concentrate, the level of feeding and passage rate were usually lower and chewing time was longer than in elder cattle, so it is expected that rumen fermentation and digestion of whole grain will be equal to ground and flaked maize. However this hypothesis has to be confirmed in experiments.

Table 1. Impact of various processing techniques on changes of maize and its fermentation into rumen and digestion in small intestine (summarizing of literature by Owens, 2005)

<table>
<thead>
<tr>
<th>Processing</th>
<th>Disrupts pericarp or exposes endosperm</th>
<th>Reduces particle size</th>
<th>Disrupts endosperm matrix</th>
<th>Disrupts starch granules</th>
<th>Increases fermentation rate</th>
<th>Increases intestinal digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry rolling</td>
<td>+++*</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Grinding</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Steam flaking</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Extrusion</td>
<td>+++</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Pelleting</td>
<td>+++</td>
<td>-</td>
<td>++</td>
<td>?</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Ensiling</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Micronization</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>?</td>
<td>?</td>
<td>+</td>
</tr>
<tr>
<td>Popping</td>
<td>++</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>?</td>
<td>+++</td>
</tr>
<tr>
<td>Protease treatment</td>
<td>-</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

* The number of + shows the degree of processing effect

Results from experiments about intake and performance of calves receiving starters in different physical forms are inconsistent. In general, multiparticle or texturized starters increase starter intake when compared with a pelleted starter (Warner et al., 1991). Franklin et al. (2003) concluded that a texturized starter would result in better performance than a pelleted or a ground starter (with no differences between these two). Porter et al. (2007) reported greater intakes of calves consuming multiparticle or texturized starters than those consuming pelleted starters. However, similar performance and starter intake were reported in the literature when calves were fed textured, coarse or ground starters, and ground or pelleted starters (Franklin et al., 2003). Almost equal intake of pelleted and ground starter and ADG was reported by Ghorbani et al. (2007).

Some authors reported a higher intake and LWG when ground starters were replaced with pelleted (Ghassemi Nejad et al., 2012) or textured (steam-flaked) starter (Owens at al., 1997; Ghasssemi Nejad et al., 2012). There are publications showing better gain of calves receiving starter with whole grain, compared to ground starter (Chester-Jones and Ziegler, 1991; Owens et al., 1997), and starter with dry rolled grain (Chester-Jones et al., 1991). Jarrah et al. (2013) do not find differences between whole, ground and steam-flaked barley, and suggest using whole or coarse ground grain as economical ingredients in starter feed for calves. Terré et al. (2015) found that calves receiving whole corn have better rumen parameters, as calves having straw in their ration. Therefore, there is some evidence that it is not need to process the grain for calves. Other authors found better results with pelleted starters (Khan et al., 2007) or with ground starter (Beharka et al., 1998) than when calves were fed whole grain. Mornill et al. (1981) established that the extrusion of a calf starter was not advantageous compared with a pelleted starter. Moreover, lower DM intakes have been observed in unground compared with ground diets that may reflect the increased time spent ruminating and the decreased rumen content flow rate in the unground diets (Beharka et al., 1998).

In calves, solid feed, especially concentrate or high carbohydrate diets, stimulates rumen microbial proliferation and VFA production and subsequently initiates rumen development. Therefore, alterations in solid feed intake and its digestibility through a certain mechanical processing method may influence the rate and extent of rumen development. Owens et al. (1997) reported that grain processing methods and degree of processing influenced DMI and digestibility. The highest intake was found in diets containing dry-rolled grains, followed by whole, steam-rolled, and steam-flaked grains, with finely ground grains resulting in the lowest feed intake.
Crockett et al. (1998) reported that starch digestibility was the highest in steam-flaked grains, followed by finely ground, and then dry-rolled grains, and was the lowest in whole grains; however, this is not always the case (Reis and Combs, 2000). Published data for digestibility in different parts of the digestive tract summarized by Owens (2005), for trials with growing cattle receiving lesser than 20% forage in diet, are presented in Table 2. Although that data do not include small calves they showed clearly differences connected with methods of processing grains, mostly maize. Data show improvements in rumen fermentation and digestibility in the small intestine after processing maize, especially ensiling high moisture grain and steam flaking.

Lesmeister and Heinrichs (2004) found that rumen development, blood VFA concentrations, and ruminal proportions production were improved by incorporation of steam-flaked corn into the calf starter, but the intake, feed efficiency, and growth were negatively affected. The effect of calf starter processing on growth and rumen development during the pre-weaning period was studied by Castro-Flores et al. (2012). They found that feeding ground, ground+forage, pelleted, and extruded calf starter did not influence body weight and hip height. Calves on the extruded treatment showed the lowest papillae height when compared to animals on the ground or ground+forage treatment. Chaves et al. (2014) found that feeding extruded starter was potentially beneficial for weight gain and morphofunctional rumen development. Extruded starter stimulated cell proliferation of the ruminal epithelium, but did not affect the dimensions of the papillary rumen and omasum mitotic index.

**Table 2.** Site and extent of starch digestion from corn-based diets by feedlot steers fed corn processed by various methods (by Owens, 2005)

<table>
<thead>
<tr>
<th>Processing method:</th>
<th>Digestibility in:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry rolled</td>
</tr>
<tr>
<td>Total tract, % of intake</td>
<td>91.0 a</td>
</tr>
<tr>
<td>Rumen, % of intake</td>
<td>63.8 a</td>
</tr>
<tr>
<td>Small intestine, % of flow</td>
<td>58.8 a</td>
</tr>
<tr>
<td>In rumen, % of total digestibility</td>
<td>70.1 a</td>
</tr>
</tbody>
</table>

Zhang et al. (2010) reported that calves consuming steam-flaked corn starter had similar ADG, milk intake, starter intake, total DMI, and body frame size, but improved feed efficiency when compared with animals consuming ground corn and extruded corn starters. ADG was generally decreased during the weaning week for all treatments, but did not differ significantly among treatments. Health incidents for calves fed the steam-flaked corn starter were fewer than in those subjected to the other dietary treatments. Hamedi-Maralani et al. (2014) however found that the calves who received steam flaked barley, ground barley, steam flaked wheat, steam flaked wheat and ground wheat had respectively 42.2%, 36.6%, 32% and 31% higher feed intake than the control group (starter diet including ground corn).

The effect of feeding of texturized calf starters containing 33% whole (WC), dry-rolled (DRC), roasted-rolled (RC), or steam-flaked (SFC) corn on the intake, growth, rumen, and blood metabolites, and rumen development was investigated by Lesmeister and Heinrichs (2004). They concluded that the type of processed corn incorporated into calf starter can influence intake, growth, and rumen parameters in neonatal calves. Post-weaning and overall starter and total DMI were significantly higher in calves fed starter with WC than SFC. Post-weaning average daily gain was significantly greater in calves fed starter with DRC than SFC. Calves consuming starter containing RC had similar body weight, feed efficiency, and rumen development, but increased frame size growth and ruminal butyrate production compared to the other corn processing treatments.

In a series of trials Bateman et al. (2009) evaluates the physical form of starters containing different types of processed corn on calf performance. They compared a pelleted versus textured starter (trial 1), textured starter versus feeding half meal starter with half textured starter (trial 2), textured starters containing whole, steam-flaked, or dry rolled corn (trial 3), textured starters containing steam-flaked versus dry rolled corn (trial 4) and textured starters containing whole or dry rolled corn (trial 5). Physical form of starter feed did not affect any measurements in trials 1, 3, 4, and 5. In trial 2, calves fed starters manufactured with large amounts of fines had by 11% lower feed intake and 6% slower ADG than calves fed a textured starter. When starters contained similar ingredient and nutrient contents, the manufacturing processes did not affect calf performance unless the diet contained a significant amount of fines, which reduced intake and ADG.

Higher starter intake, body weight and daily gain, and a more functional rumen regarding serum and rumen metabolites in calves consuming ground wheat vs dry-rolled wheat, was established by Karkoodi et al. (2014). Skeletal growth measures including body length, body barrel, withers height and hip width were not affected by treatments.

The effect of wheat processing on rumen conditions and development were investigated in an experiment conducted by Mirghaffari et al. (2013). Calves were fed starter diets containing popped wheat (PW), steam-flaked wheat (SFW), dry-rolled wheat (DRW) or ground wheat (GW). Results indicated that calves that received PW had the highest total VFA, acetate, propionate, butyrate, ammonia nitrogen, rumen wall thickness, papillar width and density. Calves fed DRW and GW experienced the lowest rumen pH throughout the experiment probably because of the high proportion of fine particles in GW. Calves consuming PW apparently had a more functional rumen in comparison with other groups. Offering rolled and whole grains as compared to a finely ground starter improved feed efficiency, growth, and body weight of dairy calves in the study of Coverdale et al. (2004).

The effect of physical form of starter diets on performance, weaning age, nutrient digestibility and rumen biochemical factors was investigated in a study by Ghassemi Nejad et al. (2012). Dietary treatments were mashed (MS), pelleted (PS), and texturized (TS) starter. They concluded that the calves receiving PS and TS diets, had significantly higher average daily gain than those receiving MS. DMI in calves fed PS and TS was greater than calves fed MS, but there was no significant difference in feed efficiency. Weaning age of calves in MS was longer than with the other two treatments. Crude protein and organic matter digestibility in MS treated calves were lower vs the other treatments. Ruminal pH was higher in MS than in the other groups, but ruminal ammonia (g/dl) concentration was not different among the treatments. Body measurements such as body length, pin width, pin to hip length, size of metacarpus and metatarsus bones, hip height, withers height, stomach size and heart girth were not significantly different among the treatments.

The effect of diet's physical form on intake and performance was investigated in a study by Bach et al. (2007). They established that the intake seemed to increase when the calves were given multi particle starters (textured feed) compared to pelleted feed. However,
the feed efficiency was higher for calves receiving pellets due to technological treatment of the feed making the nutrients more available. This resulted in same weight gain in the two groups. However, the pelleted feed turned out to be economically favorable as it increased the feed efficiency. In another study, Bach et al. (2010) evaluated the effect of physical form of starter intake and performance, however found that final body weight and feed conversion efficiency (ADG/DMI) was not affected by the physical form of starter. Bagheri et al. (2005) reported that weekly and average starter DM intake, body weight, growth rate, and weaning age were not significantly affected by the processing method of the calf starter (conventional ground or a commercial pelleted starter). The results supported the hypothesis that the easily available ground calf starter was as effective as the more costly pelleted form in promoting adequate starter intake and growth rate needed for the early weaning of dairy calves. Bittar et al. (2009) evaluated the physical form of starter concentrate (pelleted or coarsely ground) on the performance and rumen development on dairy calves. They have not identified the effect of the physical form on starter concentrate intake, body weight, and daily gain. The physical form of the concentrate also had effects neither on pH, rumen short chain fatty acids or N-NH rumen concentration, nor on the morphometric measurements of the forestomach, except for rumen capacity and abomasum weight, which were higher for animals fed pelleted starter concentrate.

The traditional ground starter appeared as efficacious for early starter intake and growth of pre-weaning dairy calves as the commercial pelleted starter. Calves fed the finely ground or the pelleted form of a similarly formulated starter concentrate had comparable average daily gain, body weight and age at daily intake of 680 g starter (Ghorbani et al., 2007). Feed pelleting and grain processing reduced weaning age and milk intake in calves but had no effect on feed intake and gain weight until the end of weaning age, when mash starter (M), pelleted starter (P) and heterogeneous mixture of moisturized, rolled barley and corn (H) were fed to neonatal Brown Swiss calves (Forughi et al., 2010).

Struisińska et al. (2009) examined the effect of whole maize and oat grains contained in starter concentrates on the performance of calves (during the first 90 days of their life) and selected morphometric parameters of the rumen and small intestine. They found that during the first 30 days, higher feed intake and daily gains in calves fed a diet containing ground cereal components. Over the entire experimental period, the supplementation of whole cereal grains to a diet allowed increasing the average daily gains of calves in the experimental group, in comparison with the control group. The addition of whole maize and oat grains to a diet positively affected selected morphometric parameters of the rumen and small intestine in calves, which was reflected in a considerable improvement in production results during the first 90 days of rearing. The obtained results indicate that it is recommended to supplement whole maize and oat grains to diets for calves, starting from the second month of life.

Pezhveh et al. (2014) researched the effects of partially replacing corn with 2 forms of wheat grain in the ration of young calves. They concluded that starter diets containing whole wheat and ground corn can improve the performance in young dairy calves compared with diets containing ground corn/ground wheat, whole corn, or ground corn.

Reviewed data show significant variation in the results of different experiments about intake of starter feeds in different physical forms and ADG of young calves. It seems clearly that ground grains with high content of fine particles in many trials have a negative effect on feed consumption and LWG. It is not however clear how effectively could be overcome the problem with fines by adding molasses to the starter feeds. Young calves are chewing very carefully which eliminate the need of grinding grains. At the same time whole grain, at least partly, has stretch effect of forages.

Whole grains especially maize are used very successfully in experiments with intake and ADG equal to starters with extensively processed grain (steam-flaking, pelleting, popping, extrusion). There is evidence for lower digestibility of whole maize and especially its starch, compared to stem-flaked or extensively processed. On the other side whole grain increased masticating and salivary flow to the rumen, which increased pH and improved rumen environment for bacterial activities and synthesis of more microbial protein. When whole grain is fed, it is probably possible to decrease or exclude forage from the diet of very young calves. Additional experiments are needed to check interactions and find the balance between different factors. Age of calves is evidently important for mentioned interactions and balances.

**Protein source of starter feed**

Soybean meal (SBM) is one of the most commonly used protein sources in calf starters (Davis and Drackley, 1998; Miller-Cushon et al., 2014) and calves fed the soybean meal-based diets performed about as well or better than calves fed diets using other sources of protein. Other protein sources like ground or extruded heat-treated soy beans, sunflower meal (SFM), canola meal (CM), corn gluten meal (CGM) and DDGS have also been successfully used for calf starters (Davis and Drackley, 1998; Montoro et al., 2010). Calves prefer soybean meal in comparison with SFM, DDGS or CM (Montoro et al., 2010; Miller-Cushon et al., 2014; Miller-Cushon et al., 2014a). However, Miller-Cushon et al. (2014a) reported that when palatable and unpalatable protein sources were mixed, it was possible to improve their palatability. Nonprotein nitrogen sources in starters are not recommended as they depress ADG and feed efficiency in young calves (Fiems et al., 1987).

The various protein sources affect the rate of protein synthesis by rumen microbes, rumen undegradable feed protein or amino acid profile. Furthermore, digestibility of diet could be influenced by the protein supplements of the diet. Fiems et al. (1985) reported that inclusion of 20% rapeseed meal in calf starters for rearing male calves to replace soybean meal decreased ration's organic matter digestibility. Mjoun et al. (2010) reported that distillers grains products were more resistant to ruminal degradation compared with soybean products, consequently more protein escaped the rumen as rumen undegradable protein in diets containing dried distiller grains. However, intestinal digestibility of lysine was higher with soybean products (97.3%) than with distillers grains (84.6%). Presflokken and Rise (2003) established that amino acid digestibility varies among feedstuffs.

Evidently, the degradability of protein into the rumen of calves before 4 months of age and especially before weaning was much lower than in aged ruminants (Vazquez-Anon et al., 1993; Holtshaussen and Cruywagen, 2000). The lack of complete development of the rumen and its microbial population in pre-weaned calves may explain the lack of conclusive benefits to formulating starters with greater share of rumen undegradable protein sources. Swartz et al. (1991), Holtshaussen and Cruywagen (2000), and Abdelgadir et al. (1996a) observed no differences in gains of calves fed diets with different rumen undegradable protein
concentrations, while Abdelgadir et al. (1996b) and Maiga et al. (1994) established improved performance when rumen undegradable protein sources were fed. McCoy et al. (2003) demonstrated trends for slower gains when RUP sources were fed. Warner (1991) reviewed research and reported no advantage to using RUP sources in calf starters. These trials showed variable results from adding RUP sources and the major part of trials reported no benefits from the inclusion of RUP sources in calf diets.

Canola is genetically improved rapeseed containing less than 2% erucic acid, having low levels of glucosinolates which directly affect diet’s palatability for livestock. When compared nutritionally to soybean meal, canola meal is lower in crude protein (32 vs. 44%), lower in metabolizable energy (11.3 vs 13.0 MJ/kg), with lower digestibility of by-pass protein into small intestine, higher in fat (3.8 vs 0.8%) and higher in both calcium and phosphorus. Experiments with canola meal have documented comparable intake and animal performance similar to soybean meal (Vincent et al., 1990). However, Miller-Cushon et al. (2014) established that calves receiving soybean meal had higher daily gain than calves fed starter with canola meal. Similar were results of Franklin et al. (2003). Data for digestibility are equivocal. Fisher (1980) reported equal digestibility of starters with canola meal and soybean meal, while Fiers et al. (1985) found lower digestibility, palatability and LWG of starter with canola meal, compared with soybean meal. Hence, experimental data for performance of calves and for digestibility of diets with soybean meal or canola meal as sources of protein in starter feed were inconsistent.

Other products like distillers grains could also be used as a protein source for calves. Chestnut and Carr (2007) reported similar average daily gain when calves were fed textured starter with soybean meal and starter with 20% dry distillers grain with solubles (DDGS). Rashid et al. (2013) found that inclusion of 25% DDGS in calf starter did not change starter intake and rumen wall and papillae development, compared to control starter. Laarman et al. (2012) reported that starch content level had no essential role in feed intake, live weight gain and feed efficiency, and that soybean meal could be replaced by DDGS and rape seeds (canola) meal. Other studies have shown that feeding distillers grains as part of a calf starter at an inclusion rate of up to 20% of the starter dry matter would result in similar body weight gain and rumen development in dairy calves (Suarez-Mena et al., 2011). However, Suarez-Mena et al. (2010) reported decreased average daily gain and digestibility of starter when DDGS comprised more than 20% of starter ingredient composition.

Lower digestibility and net energy value of canola meal and DDGS compared to soybean meal is a disadvantage, because the energy intake is a first factor determining the growth rate of calves. The higher crude fiber (acid detergent fiber and neutral detergent fiber) could not be a problem because calves need some fiber in starter feeds, as a scratch factor to prevent rumen papillae from forming keratin layers that reduce absorption (Booth, 2003). Corn DDGS could be also useful as source of fat in starter feed. Some researchers found positive effects of including ingredients improving taste, as milk products in calf starter (Mereu et al., 2013). The NRC recommendations (2001) for crude protein (CP) content in calf starter are about 18%. Trials by Akayezu et al. (1994), Luchini et al. (1991), and Hill et al. (2007) substantiate that 18% CP diets are adequate. However, Drackley et al. (2003) found that calves fed starters containing 22% CP were more efficient than calves fed starters with 18% CP. However the starter and forage intake is highly variable early in life (Jenny et al., 1991; Kertz and Chester-Jones, 2004), which makes difficult to specify what CP level would be more suitable, because it is the ingested CP amount (determined in part by the level of DM intake) and not the CP content per se, that determines growth.

Several studies have reported on the appropriate protein percentages in calf starters for optimal growth of young calves. In many instances, starter diets containing various percentages of CP, ranging from about 15% to 22%, promoted similar body weight gains. Sekine et al. (2004), Labussiere et al. (2008), Ozkaya and Toker (2012) showed that performance and feed intake of calves were not affected by CP concentration of the starters. In other cases, when incremental crude protein in starter diets was tested, live body weight gains were improved when the protein content was 17% to 18% of dry matter, except when starter consumption was restricted (Akayezu et al., 1994). In other studies the authors demonstrated no effect of CP concentration of the starter feeds on feed intake and performance of calves. Hill et al. (2005) indicated that there were no differences in the performance of calves feed 18 and 22% CP starters. However, Drackley et al. (2003) reported that calves fed starters containing 22% CP were more efficient than those fed 18% CP. Sekine et al. (2004) and Labussiere et al. (2008) showed that the performance and feed intake of calves were not affected by CP concentration of the starters. They found that starter with 25.5% CP (DM basis) provided modest benefits in starter intake (particularly around weaning) and growth for dairy calves in an enhanced early nutrition program compared to a conventional starter (19.6% CP). Starter CP content did not affect height, length, or heart girth within enhanced milk replacer treatments. In a study, Hill et al. (2007) found that calf ADG, intake, efficiency, hip width change, or body condition score change did not improve when calves were fed starter with more than 18% CP fed either as a conventional 20% CP, 20% fat milk replacer fed at 454 g/d or a 26% CP, 17% fat milk replacer fed at 680 g/d. The low content of CP could induce an excessive accumulation of body fat, while an excessive CP content is expensive and inefficient. Furthermore, excessive nitrogen to energy ratios could cause ammonia toxicity and decrease solid feed consumption (Lobley and Milano, 1997). Therefore, nutrient composition of starter concentrates must be balanced to avoid inefficient use of protein, deposition of excess fat, and lower digestibility.

It is evident that so far there are not enough data about the interactions between the two main sources of protein for pre-weaning calves – milk or milk replacers and starter feeds. Data about possibilities to use different plant protein sources are based more on fiber content and digestibility of organic matter, than on the quality of protein (degradability, amino acid content and digestibility, palatability). It is obvious that it is possible to include canola meal, DDGS, sunflower meal and other protein sources in calves diet, but there are no current data on the level of replacement of soybean meal without decreasing intake of dry feeds and ADG. The information about the best combination of the main protein sources for calves is also insufficient. It is not clear whether it is possible to decrease the quantity of hay or other forage and to increase protein sources with higher fiber content or whole grains in diet and to what extent.

Conclusions

The fast digestive tract morphological and functional development in young calves makes difficult the study and clear identification of the effects of processing grain and other portions of calf starter diet, as well as requirements to the quality of protein...
Sources in diet (degradability, amino acid content and digestibility, palatability etc.). The contradictory data on the impact of physical form and protein sources in calves' starter feeds demand additional studies to obtain more information on the interactions between the physical form of starters, rumen fermentation environment and age of calves. For the Balkan area and many other regions a clear answer to the question about the best possible extent of replacing the expensive soybean meal in the rations with sunflower meal, canola meal, dry distillers grain with solubles or combination of them is very important. It is speculated that during the milk feeding period, especially when calves do not receive forage, whole grain is probably digested as efficiently as the extensively processed maize.

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