Achievements in the Life Sciences 10 (2016) 187–196

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Achievements in the Life Sciences

journal homepage: www.elsevier.com/locate/als

Sub-acute Ruminal Acidosis (SARA) and its Consequence in Dairy Cattle: A Review of Past and Recent Research at Global Prospective

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A R T I C L E I N F O

Article history:
Received 31 October 2016
Accepted 16 November 2016
Available online 26 November 2016

Keywords:
Dairy cattle
SARA
Sub-acute ruminal acidosis
Ruminal acidosis

A B S T R A C T

Dairy producer increase milk production by over feeding grain diets that are high in starch and low in fiber to increase intake of energy and met dietary requirements of the high yielding dairy cows. However, these diets increase the risk of subacute ruminal acidosis (SARA). Thus, maximizing milk production without incurring Sub-acute ruminal acidosis is a challenging most dairy producers. The main aims of this paper were to review available article on general aspects of Sub-acute ruminal acidosis and its consequence in dairy cattle by focusing on past and recent article and helping to update the current knowledge for early recognition and limit the associated negative impact in dairy industry. Sub-acute ruminal acidosis is a well-recognized and economically important digestive disorder found particularly in well-managed dairy cattle. It is a consequence of feeding high grain diets to dairy cows and characterized by daily episodes of low ruminal which generally occurs when ruminal pH stays in the range of 5.2 and 6 for a prolonged period resulting in depresses fiber digestion and possibly milk production. There is no typical clinical sign of illness in SARA affected cows. However, SARA is said to be associated with inflammations of different organs and tissues in dairy cows. Rumenocentesis remains the most reliable means of diagnosing SARA. The cow at risk to develop SARA includes cows in the early lactation, Primiparous cows and Cows grazing or fed with rapidly fermentable low fiber grass. SARA has long-term health and economic consequences, which include feed intake depression, fluctuations in feed intake, reduced diet digestibility, reduced milk yield, reduced milk fat percent, gastrointestinal damage, liver abscesses, and lameness. Apart from compromises to dairy cow health and economics, SARA is of concern for animal welfare reasons, since lameness and laminitis impact significantly on cow comfort and general well-being. Thus, it represents a significant concern for dairy industry and the cattle should be regularly monitored to facilitate early recognition of the condition and limit the associated economic losses.

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Peer review under responsibility of Far Eastern Federal University.

http://dx.doi.org/10.1016/j.als.2016.11.006

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Introduction

Over the last few decades, the productivity of dairy cows has increased greatly. However, As milk yield increases, the management challenge of meeting a cow's dietary nutrient needs becomes greater (Sundrum, 2015). Currently in many dairy herd situations, milk production can appear to be temporarily increased by over- feeding grain because dietary requirements of energy and fiber are not easily met for the high yielding dairy cows (Kmicikewycz, 2014; Oetzel, 2007). This is especially true for early lactation cows because their energy expenditure exceeds the energy consumed. Diets high in starch and low in fiber are fed to increase intake of energy, but these diets increase the risk of subacute ruminal acidosis (SARA) (Kmicikewycz, 2014; Oetzel, 2007; Krause, 2008; Krause and Otzel, 2006; Bipin et al., 2016). Sub-acute ruminal acidosis is a well-recognized digestive disorder of high yielding dairy cows that has negative impact in both animal health and herd profitability particularly in well-managed dairy herds (Kitkas et al., 2013; Plaizier et al., 2014; Enemark, 2008; Antanaitis et al., 2015; Kleen et al., 2013). This digestive disorder is the consequence of feeding high grain diets to dairy cows, which are adapted to digesting predominantly forage diets. The current definition and ruminal pH threshold for SARA vary among studies. However, SARA generally occurs when ruminal pH stays in the range of 5.2 and 6 for a prolonged period (Li et al., 2013). SARA is characterized by daily episodes of low ruminal pH (Krause and Otzel, 2006), during which rumen pH is depressed for several hours per day (Plaizier et al., 2014) due to accumulation of volatile fatty acids and insufficient rumen buffering (Plaizier et al., 2008).

There is no typical clinical sign of illness in SARA affected cows (Krause and Oetzel, 2005; Mutsvangwa et al., 2002; Tajik and Nazifi, 2011). However, SARA is said to be associated with inflammations of different organs and tissues in dairy cows. Its consequences are diverse and complex, which include feed intake depression, fluctuations in feed intake, reduced diet digestibility, reduced milk yield, reduced milk fat percent, gastrointestinal damage, liver abscesses, and lameness (Krause and Otzel, 2006; Plaizier et al., 2008; Radostits et al., 2007). Injury to the gastrointestinal lining followed by localized or systemic inflammation appears to mediate many of these negative effects.

Prevalence of SARA in dairy herds is not well studded. However, it is an increasing problem for the dairy industry, even in well-managed, high-yielding dairy cattle. Its prevalence increases as cows consume more total DM and as cows consume diets containing higher proportions of grain (Krause and Otzel, 2006). Prevalence of SARA has been documented from 19 to 26% in early to mid-lactation cows (Garrett et al., 1997; Oetzel et al., 1999). Kleen, (Kleen, 2004) indicated the incidences of SARA in early and mid-lactation cows to be 11% and 18%, respectively. In addition, recently Kleen et al. (2013) reported 20% prevalence out of 315 cows in Northern Germany. Furthermore, the most recent study by Stefańska et al. (2016) also found 14% prevalence from a total of 213 cows. Thus, SARA is the most important nutritional disease and represents a significant concern as it can negatively impacts the dairy industry by decreasing dry matter intake, milk production, profitability, and increasing culling rate and death loss (McCann et al., 2016). However, there is paucity of well documented information on its general aspect and consequence in dairy cattle. Therefore, the main objectives of this manuscript were to review the general aspects of Sub-acute ruminal acidosis including it clinical sign, diagnostic methods and its consequence in dairy cattle by focusing on both past and recent researches at global prospective.

Literature Review

Definition and General Aspects of SARA in Dairy Cattle

Ruminal acidosis is a bovine disease that affects feedlot as well as dairy cattle. By definition, acidosis is a decrease in the alkali (base excess) in body fluids relative to the acid (hydrogen ion) content (Owens et al., 1998; Dehkordi and Dehkordi, 2011). Ruminal acidosis is usually associated with the ingestion of large amounts of highly fermentable, carbohydrate-rich feeds which result in the excessive production and accumulation of lactic acid in the rumen. It can be present in different forms, reaching from peracute life-threatening forms to chronic illness, which is difficult to detect (Oetzel, 2003).

The diference between acute and subacute forms are that during acute ruminal acidosis, the pH depression is more severe, the concentration of lactic acid in the rumen digesta is higher, and the clinical signs more prominent (Plaizier et al., 2014; Kleen et al., 2003a). Acute rumen acidosis is common in feedlots, whereas Subacute ruminal acidosis (SARA) is more common on dairy farms (Krause and Otzel, 2006). Compared with acute ruminal acidosis, SARA is not associated with accumulation of lactic acid in the rumen ((Oetzel et al., 1999). SARA, the periods of rumen pH depression below physiological range, is the consequence of feeding high grain diets to dairy cows, which are adapted to digesting predominantly forage diets. It is characterized by daily episodes of low ruminal pH and most common in high yielding dairy cows under intensive livestock production systems (Krause and Otzel, 2006; Kleen et al., 2013). The depression of ruminal pH in dairy cattle with SARA is apparently due to the total accumulation of volatile fatty acids alone and is not due to lactic acid accumulation (Krause and Otzel, 2006).

Current definitions of SARA are based on rumen pH, determined by various methods (Oetzel, 2003; Kleen et al., 2003a; Plaizier et al., 2009; Stone, 2004). Unfortunately, the definition varies greatly, and the definition and terminology are not uniform throughout the literature. Thus, it is challenging to set up a specific threshold of rumen pH for defining SARA, since rumen pH varies among different sites inside of the rumen. The use of different techniques to collect rumen fluid for pH determination introduces further variation. The highest rumen pH usually observed in the cranial dorsal sac, followed by the cranial ventral, caudal ventral, and the caudal dorsal sac. Rumen pH in the ventral sac and the center of rumen solid mat is the lowest (Duffield et al., 2004; Shen et al., 2012). When using a stomach tube 4-h post feeding, Plaizier (2004) used a rumen pH of 6.0 as a threshold. Garrett et al. (1999) defines SARA with a threshold of 5.5 using rumenocentesis. Duffield et al. (2004), on the other hand, observed that ruminal fluid collected from the ventral sac of the rumen through a cannula and through a stomach tube were 0.33 and 0.35 pH units higher than fluid collected by rumenocentesis. Based on those findings, those authors therefore proposed that thresholds for abnormal pH indicating SARA should be 5.5, 5.8 and 5.9 when rumen fluid samples are collected by rumenocentesis, through a rumen cannula from the ventral sac, and using an oral probe, respectively.

During subacute ruminal acidosis (SARA) rumen pH is depressed for several hours per day due to accumulation of volatile fatty acids and insufficient rumen buffering (Plaizier et al., 2008). Rumen pH fluctuates diurnally between nearly neutral before morning feeding and acidic after feeding. When cows are fed by high forage diets, rumen pH can be maintained between 6 and 7, which is considered to be the optimum for cellulolytic bacteria**.** Ruminal pH may decline periodically below 6 when dietary grain content increases. Generally, SARA occurs when ruminal pH stays in the range of 5.2 and 6 for a prolonged period (Li et al., 2013)**.**

Etiology, Prevalence and Risk Factors of SARA in Dairy Cattle

Etiology

Nutritional Causes of SARA include inadequate ruminal buffering, inadequate Adaptation to high carbohydrate diets. Diets with excessive (over about 15%) long forage particles can paradoxically increase the risk for SARA. This happens when the long particles are unpalatable and sortable. Sorting of the long particles occurs soon after feed delivery, causing the cows to consume a diet that is low in physically effective fiber after feeding (Oetzel, 2007). The known principles of ruminal adaptation suggest that increasing grain feeding toward the end of the dry period should decrease the risk for SARA in early lactation cows. However, increased grain feeding the dry period had no beneficial effect on early lactation ruminal pH or dry matter intake. In general major causes for subacute ruminal acidosis are lack of coarse fiber and/or excess concentrates in the diet, feed sorting, rapid diets changes, and engorging (Plaizier et al., 2006).

Prevalence

Prevalence of SARA in dairy herds is not well studded. However, it is an increasing problem for the dairy industry, even in well-managed, high-yielding dairy herds. Its prevalence increases as cows consume more total DM and as cows consume diets containing higher proportions of grain (Krause and Otzel, 2006). Some of the field studies revealed the presence of SARA in 11–29.3% of the early lactation cows and in 18–26.4% of the mid-lactation cows (Garrett et al., 1997; Kleen, 2004; Tajik et al., 2009). The prevalence of SARA in intensive dairy production has been found to range between 11 and 26% (Plaizier et al., 2008; Garrett et al., 1997; Oetzel et al., 1999; Tajik et al., 2009). A screening of 15 Holstein herds in the US revealed the presence of SARA in 19% of the early lactation cows and in 26% of the mid-lactation cows. In one-third of the herds observed more than 40% of the total numbers of cows within the herd were found to have SARA (Garrett et al., 1997). Oetzel et al. (1999) detected SARA in 20.1% of early and peak lactation cows. In Netherlands, Kleen et al. (2009) reported an overall prevalence of 13.8%, and prevalence on individual farms ranging from 0% to 38%. In study by O'Grady et al. (2008) 11% of cows were classified as affected with SARA. Morgante et al. (2007) surveyed 12 dairy farms in Italy and included 10 cows in each herd between 5 and 60 days in milk (DIM). They found that in 3 out of the 10 herds the prevalence of SARA was greater than 33%. Furthermore, in a German/Dutch study, incidences of SARA in early and mid-lactation cows were found to be 11% and 18%, respectively (Kleen, 2004). Kleen et al. (2013) reported a SARA prevalence of 20% with a great variation in the SARA prevalence among farms in a survey including 315 cows on 26 farms in Northern Germany. The study by Stefańska et al. (2016) also found 14% prevalence from a total of 213 cows.

Risk Factors

The cow at risk to develop SARA includes Cows in the early lactation, Primiparous cows and Cows grazing or fed with rapidly fermentable low fiber grass (Li et al., 2013). Cows in the early lactation are probably due to the instability of the bacterial population (Devries et al., 2009). According to Stone (2004) cows might be at greatest risk for SARA immediately postpartum due to diminished size and absorptive capacity of rumen papillae following feeding of lower energy density diets during the dry period. Enemark et al. (2004) indicated that primiparous cows were generally more prone to low ruminal pH, higher ruminal concentrations of volatile fatty acids and possibly to metabolic acidosis, than multiparous cows. Krause and Otzel (2006) also indicated higher prevalence of SARA in primiparous cows than in multiparous cows. Cows are apparently at higher risk for SARA in the summer due to lack of ruminal buffering caused by heat stress, increased respiratory rate, respiratory alkalosis, and low blood bicarbonate concentrations. Other causes of increased SARA in the summer months could include atypical meal patterns in response to heat avoidance and ration formulation errors made when nutritionists attempt to compensate for reduced dry matter intake during heat stress by decreasing dietary fiber (Oetzel, 2007). Other well-known risk factors for SARA are errors in ration formulation and preparation (false dry matter calculation), errors in TMR mixing and managerial factors like feeding time-schedule and feed bunk space per cow (Kleen et al., 2003a).

Clinical Signs of SARA

There is no typical clinical sign of illness in SARA affected cows (Krause and Oetzel, 2005; Mutsvangwa et al., 2002; Tajik and Nazifi, 2011). However, SARA is said to be associated with inflammations of different organs and tissues in dairy cows. A physical examination may reveal the presence of subcutaneous abscesses, which are not related to injections (Nordlund et al., 1995). Clinical signs from the health effects of SARA are delayed in onset from the time of the low ruminal pH insult. These signs are the result of a pathophysiological cascade of events that begins with rumenitis. Once the ruminal epithelium is inflamed, bacteria may colonize the papillae and leak into portal circulation. These bacteria may cause liver abscesses, which sometimes cause peritonitis around the site of the abscess. If the ruminal bacteria clear the liver (or if bacteria from liver infections are released into circulation), they may colonize the lungs, heart valves, kidneys, or joints. The resulting pneumonia, endocarditis, pyelonephritis, and arthritis are all chronic inflammatory diseases that are difficult to diagnose ante-mortem (Oetzel, 2007).

Some of the SARA attributed clinical signs such as rumenitis, rumen parakeratosis, liver abscesses and pulmonary bacterial emboli are detectable at the time of autopsy and show previous periods of acidosis. Other clinical signs that have been noted by some authors are the presence of fibrin casts in feces, excessive body fecal soiling, continuous tail swishing, dropping the cud while ruminating, poor reproductive performance and environmental mastitis (Grove-White, 2004). Although, rumen hypomotility has been considered as a probable clinical sign of SARA affected cows (Duffield et al., 2004), no difference was observed between the SARA affected and the non-affected cows in the number and quality of rumen contractions (Tajik et al., 2009). SARA may also be associated with laminitis and subsequent hoof overgrowth, sole abscesses, and sole ulcers. The ruminal epithelial cells are not protected by mucus (as abomasal cells are), so they are vulnerable to the chemical damage by acids. Thus, low ruminal pH leads to rumenitis, erosion, and ulceration of the ruminal epithelium. Rumenitis is the fundamental lesion of SARA, and it leads to chronic health problems (Oetzel, 2007). Some of the most common clinical signs are discussed below.

Decreased Dry Matter Intake

Decrease in dry matter intake is often presented as a consistent sign and sensitive indicator of SARA (Stock, 2000; Garry, 2002) and has been used as a clinical sign to diagnose SARA (Oetzel, 2003; Kleen et al., 2003a). Several studies have shown a lowered feed intake during periods of SARA (Antanaitis et al., 2015; Brown et al., 2000; Olsson et al., 1998; Krajcarski-Hunt et al., 2002; Eun et al., 2014; Danscher et al., 2015). A 25% decrement in Total Mixed Ration (TMR) intake has been observed during induced SARA periods (Kleen et al., 2003a)). The Study by Krajcarski-Hunt et al. (2002) also revealed a 25%-decrease in the intake of a TMR during SARA-periods induced, compared to normal. Moreover, the digestion of feedstuffs was generally impaired. Reasons for the feed intake depression can include reduced fiber digestibility and increases in volatile fatty acids, especially propionate, and in the osmolarity in the rumen (Plaizier et al., 2008; Allen, 2000).

Laminitis

The scientific name for laminitis is "pododermatitis aseptic diffusa". Translated it means an aseptic inflammation of the dermal layers inside the foot (Nocek, 2001). Laminitis, an aseptic inflammation of the hoof dermal layers, is the major source of lameness which is a major health and welfare concern for the dairy industry (Shaver, 2005). Nutrition, especially acute and subacute ruminal acidosis, is associated with laminitis. Although, the exact relationship between SARA and laminitis is not known (Stone, 2004), subacute or chronic laminitis has been described in SARA affected cows and its clinical signs are discoloration of the hoof, sole hemorrhages, sole ulceration and misshapen hooves (Nordlund et al., 1995). Some authors believe that chronic laminitis is the most consistent and significant clinical sign of a herd with SARA and a prevalence of more than 10% is maintained as being indicative of a SARA problem in a herd (Nordlund et al., 1995; Enemark et al., 2002). However, the causes of laminitis and associated claw horn lesions are multi-factorial in nature (Nordlund, 2004) and a combination of many factors, such as genetics, conformation characteristics, manure handling system and the presence or absence of some infectious diseases affect the prevalence of SARA triggered laminitis in a herd (Shaver, 2005; Cook et al., 2004).

Loss of Body Condition and High-Culling Rate

Subacute ruminal acidosis is often named as one reason for a low body condition (Nordlund et al., 1995; Nocek, 1997; Oetzel and Smith, 2000). During SARA, ruminal accumulation of short-chain fatty acid (SCFA) reduces rumen pH and causes a shift in rumen microflora (Zebeli and Metzler-Zebeli, 2012). Fiber and total carbohydrate digestion are reduced as a consequence of this shift, resulting in a loss of energy, and reduced body condition is sometimes noted without a concurrent reduction in intake (Hall, 2002; Kleen et al., 2003b; Dijkstra et al., 2012). Thus, in SARA affected dairy herds there are a number of thin cows despite a high energy diet (Kleen et al., 2003a; Nordlund et al., 1995). Reasons for poor body condition may be chronic inflammation, which may presumably antagonize growth by releasing cytokines generally opposing anabolism as well as decreasing DMI in a situation of impaired general health (Oetzel, 2003) However, body condition score could not be used to differentiate between SARA affected and non-affected cows in a dairy herd (Kleen, 2004; Tajik et al., 2009). A farmer may try to correct the possibly occurring loss of body condition, originating from SARA, by increasing the energy level of the ration, thus exaggerating the basic acidosis problem (Nordlund et al., 1995).

In SARA affected herds the culling rate and number of inexplicable deaths are exceptionally high (Enemark et al., 2002). In these herds the annual herd turnover rate is greater than 45% and the annual cull rate is greater than 31%. The culling reasons are indistinct and unexplained death, lameness, loss of body condition and non-responsive pathological conditions are probably the most important causes (Oetzel, 2003; Kleen et al., 2003a; Nordlund et al., 1995). However, similar to lameness, a high culling rate in an affected dairy herd may be unuseful in SARA diagnosis when only some subgroups of cows experience it.

Alterations in Feces, Diarrhea

Changes in fecal consistency, structure and the pH of SARA affected cows have been described. In a SARA affected group, variable fecal consistency and many cows with loose feces are seen. It is believed that the pH of feces in SARA affected cows is lower than normal and the size of ingesta particles may be larger than normal (Kleen et al., 2003a; Grove-White, 2004). However, as the fecal alterations are usually transient and only a few animals have loose feces at one time, these animals are usually not noticed (Kleen et al., 2003a; Nordlund et al., 1995). In SARA cases, the feces are bright, yellowish, have a sweet–sour smell (Kleen et al., 2003a), appear foamy with gas bubbles, and contain more than normal amounts of undigested fiber or grain. Because there is an insufficient ruminal fiber mat, the fiber is not effectively retained in the rumen so the feces contain 1–2 cm sized fiber particles compared to the more normal size of 0.5 cm (Hall, 2002). Gakhar et al. (2008) found that experimental SARA induction had no effect on fecal pH. Nordlund (2004) believes that because dietary fiber had no effect on fecal consistency and fecal pH is an indicator of small intestinal pH but not necessarily ruminal pH, fecal evaluation has very limited value in monitoring or diagnosing SARA in dairy herds. Nordlund et al. (1995) reported on herds with loose feces that contained substantial amounts of undigested feed particles. Intermittent diarrhea and the presence of undigested particles indicate inadequate digestion and fast passage of feed. Diarrhea has been associated with SARA in dairy herds (Oetzel, 2003; Kleen et al., 2003a; Nocek, 1997).

Milk Fat Depression

The relationship between SARA and milk fat depression is controversial and complex. Several factors, such as lactation state, breed and composition of feed rations affect the fat percentage of milk (Enemark et al., 2002). Ruminal acidosis is the third major rule-out as a cause for milk fat depression. It apparently causes milk fat depression by inhibiting bacteria responsible for fatty acid biohydrogenation in the rumen. Thus, more trans fatty acids are absorbed, even if the intake of unsaturated fatty acids was not necessarily high (Oetzel, 2007). A depression of milk fat percentage in SARA affected cows has been documented by some authors and alterations in the ruminal fermentation pattern has been introduced as the cause of the depression (Kleen et al., 2003a). In a case study of 500 dairy cows, a decrease in milk production of 3 kg/cow/day and decreased milk fat from 37 to 34 g kg-1 were calculated (Xu et al., 2016). However, it is believed that a decrease of milk fat usually occurs in individuals and remains undetectable in bulk tank testing (Kleen et al., 2003a)). In herds with multiple rations, some subgroups may experience SARA and the effect may be masked by pooling their milk with the rest of the herd. Nordlund (2004) indicated that a milk fat percentage below 2.5% in 10% of the cows in a Holstein herd is possible evidence for SARA.

In study by Danscher et al. (2015) Milk fat content was decreased in the SARA induced group (4.14%) compared to the control group. In addition Xu et al. (2016), Bipin et al. (2016) and Malekkhahi et al. (2016) reported reduced milk fat content during SARA. On the other hand, low milk fat content was not observed during some of the experimental inductions of SARA (Enjalbert et al., 2008) and some researches have shown that SARA affected cows had no milk fat depression in farm condition (Tajik et al., 2009; Oetzel, 2005). Some authors have suggested that the inconsistent response in milk fat in experimentally-induced SARA may be related to the duration of the bouts of SARA (Krause and Oetzel, 2005; Oetzel, 2005) believes that short-term SARA challenges have no effect on the milk contents.

SARA Diagnostic Techniques

Since signs of SARA are not completely known and the diagnosis is often difficult in the field due to the variable and subtle signs. Additionally, some of the SARA signs may appear several weeks or months after SARA occurrence. Thus, Lack of pathogonomic signs and the delayed appearance of some clinical signs cause SARA to remain unrecognized in some dairy herds. On the other hand, SARA occurrence in herds which are suspected to be SARA affected by the appearance of some clinical signs needs to be confirmed (Tajik and Nazifi, 2011). Diagnosis of SARA based on the rumen fluid has been recommended by several authors, as it gives direct information about the rumen condition (Tajik and Nazifi, 2011; Kleen et al., 2003a; Duffield et al., 2004; Nordlund et al., 1995). Nordlund (2003) observed that the experimental induction of SARA affects the milk fatty acid profile and believe that the fatty acid profile can be used as a diagnostic tool for SARA. According to Li et al. (2013) feeding behavior can also be used as a diagnostic tool in dairy cows. The most common SARA Diagnostic Techniques and tips are discussed below.

Rumen pH Determination

Although, there is no general agreement on the pH threshold that is definitive of SARA and a rumen pH of ≤5.5, between 5.2 and 5.5, <5.6 and <6 have been suggested as the threshold for SARA (Khafipour et al., 2009), the current definition of SARA is based on rumen pH. The methods of obtaining rumen fluid for the measurement of rumen pH are described as follows.

Rumenocentesis Technique. Rumenocentesis was presented by Nordlund et al. (1995) for SARA diagnosis in dairy herds. In this method, rumen fluid is obtained using percutaneous needle aspiration from the caudoventral rumen. Duffield et al. (2004) reported rumenocentesis as a better field test in comparison to the oro-ruminal probe for the measurement of rumen pH. The pH of ruminal fluid that was collected by rumenocentesis had a positive linear relationship with the pH of that collected through a ruminal cannula and rumenocentesis samples were about 0.28 pH units lower than the samples collected simultaneously through rumen cannula (Garrett et al., 1997). The puncture site is located 12 to 15 cm caudal to the costochondral junction of the last rib, on a horizontal line level with the top of the patella. Before rumenocentesis the puncture site should be clipped, disinfected (scrubbing with povidone-iodine or chlorhexidine) and locally anesthetized (with S.C. and I.M. injection of lidocaine). The puncture can be carried out by an 18 gauge, 100–120 mm long, stainless steel needle and 3–5 mL of ruminal fluid can be aspirated using a 10 mL syringe (Garrett et al., 1997; Nordlund, 2003). The disadvantage associated with this method is that it is quite invasive, and can result in abscesses at the site of puncture (Aceto et al., 2000). Haematomas and abscess formation at the puncture site and septic peritonitis have been reported in different proportions of sampled cows (Kleen, 2004). Strabel et al., 2007) reported abscess formation in 7 out of 12 cows after one to three rumemenocentesis. Aceto et al. (2000) reported rumenocentesis causes a 16% decrease in the milk production of sampled cows.

Oral - Stomach Tube Technique. It is generally accepted that sampling and evaluation of rumen fluid using a stomach tube is not a reliable technique in the diagnosis of SARA. Stomach tubing is time consuming and the pH of the sampled rumen fluid is questionable because the pH may vary depending on the intra-ruminal localization of the stomach tube, saliva contamination and time of sampling in relation to feeding (Enemark et al., 2002).

Rumen Cannula Method. Ruminal cannulation is the preferred method of obtaining representative samples of ruminal fluid (Nocek, 1997), however, this method is limited to research proposes. In this method the repeated removal and replacement of the cannula cover disturb the animal and may allow digesta to escape (Tajik and Nazifi, 2011)

Indwelling pH Data Logger Method. The best way to evaluate rumen pH fluctuation is to insert a pH probe directly into rumen digesta and record its pH at real time (Dado and Allen, 1993). Indwelling rumen pH device are commercially available and comes with a built-in data logger as well as the wireless communication technology (Penner et al., 2006).

Other Diagnostic Tips

Manure Evaluation. The increase in grain content in diets, which may induce SARA, can also result in more dietary nutrients bypassing the rumen and reaching the hindgut. Excessive hindgut fermentation then changes the consistency and appearance of the manure. Hence, manure observation may be used as a diagnostic tool to evaluate rumen functionality (Hall, 2007). If the rumen functions normally, only few recognizable feed particles should be observed in manure and the size of the particles should be no longer than half an inch. Watery and foamy manure indicates the abnormal fermentation in the hind gut, and mucin casts in manure suggests the damage of gut epithelium (Li et al., 2013; Hall, 2007).

Fecal Lipopolysaccharide (LPS). Feeding high-grain diets to induce subacute ruminal acidosis (SARA) in dairy cows has been associated with the increase in the concentration of lipopolysaccharide (LPS) endotoxin originating from gram-negative bacteria in feces (Li et al., 2012). Gakhar et al. (2008) found that experimental induction of SARA increases the LPS concentration in feces. Plaizier et al. (2009) reported that dairy farms with low dietary NDF had higher fecal LPS, about 2 times greater, than farms with a high dietary NDF. They proposed that fecal LPS could aid in the diagnosis of SARA.

Blood Gas Analysis. Gianesella et al. (2010) indicated that blood gas analysis is a valuable tool to diagnose acidosis in dairy cows because it provides good assessment of acidosis while being less invasive than rumen pH analysis. Given that SARA is characterized as an acid overload in the rumen, it is logical to speculate that SARA may cause an acid–base imbalance in blood. Hence, blood gas analysis may be helpful for diagnosing SARA. Although, a slight decrease in blood pH and bicarbonate, as well as a slight change in the base excess have often been reported following the experimental induction of SARA, in some cases a more significant marked decrease in the blood bicarbonate and base excess during subacute acidosis have been observed (Brown et al., 2000; Bevans et al., 2005). Kleen et al. (2003a) indicated that blood pH and base excess may be of use in diagnosis of SARA. A survey on dairy farms indicated that cows at high risk of SARA had relative high pCO2, low pO2, and low blood pH (Gianesella et al., 2010). In the laboratory, a significant increase pCO2 and unchanged pO2 was observed in SARA-challenged cows (Li et al., 2012).

Consequences of SARA in Dairy Cattle

Being the most important nutritional disease affecting dairy cattle (Enemark, 2008; Mohebbi Fani et al., 2010), SARA has Long-term devastating health and economic consequences dairy cattle, which include feed intake depression, fluctuations in feed intake, reduced diet digestibility, reduced milk yield, reduced milk fat percent, gastrointestinal damage, liver abscesses, and lameness (Krause and Otzel, 2006; Plaizier et al., 2008; Radostits et al., 2007). Apart from compromises to dairy cow health and economics, SARA is also concern for animal welfare reasons, since lameness and laminitis impact significantly on cow comfort and general well-being (Oetzel, 2003; Hall and Averhoff, 2000). Lameness is probably most important animal welfare issue today in dairy herds, and a good portion of the lameness observed in dairy cows may be attributed to laminitis secondary to high grain feeding. Public perception of dairy production is becoming increasingly important, and lame cows do not portray a good image of our industry. Lameness (along with secondary reproductive failure and low milk production) is commonly the most important cause of premature, involuntary culling and unexplained cow deaths in a dairy herd (Oetzel, 2007). SARA has also been proposed as the predisposing factor for some diseases, such as hemorrhagic bowel syndrome (Tajik et al., 2010).

It is obvious that SARA is of great economic importance to the dairy industries. Financial losses caused by SARA result from decreased milk production, decreased efficiency of milk production, premature culling, and increased death loss (Krause and Oetzel, 2005). In a case study conducted on a 500-cow dairy in central New York, Stone (1999) calculated a cost of $400 to $475 lost income per cow per year due to SARA. Donovan (1997) estimated the annual cost of sub-acute ruminal acidosis (SARA) to the US dairy industry at $ 500 million to $ 1 billion. The condition affects more than 20% of cows (Plaizier et al., 2008; Hall and Averhoff, 2000). The field study on a large dairy farm in New York State found that SARA reduced milk yield by 2.7 kg/day, milk fat production by 0.3% points and milk protein production by 0.12% points (Stone, 1999). The percentage reduction of milk fat and milk protein applied to an entire lactation using these reductions can amount to a financial loss of as much as $400 per cow per lactation. These costs exclude costs due to increased culling and veterinary treatments. Recent modeling methods to assess cost of different types of lameness showed sole ulcers, a common consequence of SARA due to laminitis lesions, cost producers $216 per case with 38% of the costs resulting from milk loss (Cha et al., 2010).

SARA may indirectly affect fertility in addition to calving and possibly the health of the newborn calf. Thus, a cycling feeding pattern or decrease in DMI during early lactation may, via the subsequent energy shortage, result in insufficient maturation of the first wave of post partum ova (Britt, 1995). Ruminal acidosis can be a direct human health concern as well. Low ruminal and intestinal pH due to high grain feeding increases the risk for shedding enterohemorrhagic *E. coli* such as 0157:H7 (Russell and Wilson, 1996). Switching cattle to a high forage diet just prior to slaughter decreases this shedding (Oetzel, 2007).

Conclusion

Sub-acute ruminal acidosis (SARA) is one of the most important metabolic diseases in modern dairy industry that impairs cow performance and health even well managed and high yielding dairy cows. Furthermore, it has concern of animal welfare reasons due to lameness and laminitis impact significantly on cow comfort and general well-being. The cow at risk to develop SARA includes cows in the early lactation, Primiparous cows and cows grazing or fed with rapidly fermentable low fiber grass. The SARA has diverse and complex consequences, which include feed intake depression, fluctuations in feed intake, reduced diet digestibility, reduced milk yield, reduced milk fat percent, gastrointestinal damage, liver abscesses, and lameness. It therefore increases the cost of veterinary care. In much dairy herd milk production can appear to be temporarily increased by overfeeding grain and causing SARA to remain an important dairy cow problem. Thus, the cattle should be regularly monitored to facilitate early recognition of the condition and limit the economic losses associated with SARA.

List of Abbreviations

DIM	Days in Milk
DMI	Dry Matter Intake
LPS	Lipopolysaccharide
NDF	Neutral Detergent Fiber
SARA	Sub-Acute Ruminal Acidosis
SCFA	Short-Chain Fatty Acid
TMR	Total Mixed Ration

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Materials

Not applicable.

Funding

Not applicable.

Authors' Contribution

Not applicable (single author).

Competing Interests

Author declare no competing interests.

Acknowledgements

Not applicable. Words are inadequate to express my deep sense of indebtedness to my sister Nebati Abdela for her encouragements and continuous support. Next I would like to thanks Jimma University for facility support and internet access.

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