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The Effects of Grass-Based versus Grain-Based Feeding of Ruminants on the Human Hygienic Status, a Review

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ABSTRACT

Ruminant meat quality is one of the important factors contributing to the recent spreading of several diseases, such as obesity, cancer, and cardiovascular problems, which have increased predominately. Feeding regiment plays an important role in the determination of the composition of fatty acids and meat quality in ruminants. This review aims to highlight the main factors that lie behind the variability of ruminant meat quality and its effect on human being's health. The reduction in grass-feeding decreases saliva levels in the ruminants, which has several consequences on the rumen, including a reduction in pH level, along with a reduction in the microorganism activities and conjugated linoleic acid levels. In adipose tissues, the expression of the stearoyl-CoA desaturases gene is negatively affected by the decreased conjugated linoleic acid levels in the rumen, which leads to a decreased transformation of saturated fatty acids to monounsaturated fatty acids. Therefore, the lower monounsaturated fatty acids and the parallel increase in the proportion of saturated fatty acids in the consumed meat can be associated with some human diseases. Thus, the present study provided a molecular explanation for the superiority of grass-based feeding in ruminants raised at pasture in term of production of meat with a healthier quality for consumers than those raised on grains.

Key words: Grain; Grass, Human disease, Ruminant meat, SCD enzyme

INTRODUCTION

Ruminant meat plays a key role in human nutrition, as it provides an inevitable source for high-quality protein (Quiñones et al., 2017). Moreover, it is a proven reservoir for essential micronutrients and several bioactive lipids (Shingfield et al., 2013). On the other hand, meat is a main source of fat in the diet and particularly Saturated Fatty Acids (SFA), (Coutinho et al., 2014) which have been related to the recent spreading of several diseases in humans, such as Cardiovascular Diseases (CVDs), obesity, diabetes, cancer, neurological and skin damages (Makkar and Beever, 2013; Savoini et al., 2016; Hilmia et al., 2017; Temple, 2018). Atherosclerotic complications are primarily responsible for elevated morbidity and mortality in many people around the world (Mansour and Ajeel, 2013). It is estimated that 17.5 million individuals die from CVDs annually, accounting for 31% of all deaths worldwide (WHO, 2016). Impaired insulin sensitivity has been reported due to saturated fats which pose specific lipotoxicity to pancreatic β cells. Thus, replacing SFA with Monounsaturated Fatty Acids (MUFAs) has a role in the improvement of lipoprotein and glycemic levels in individuals with type 2 diabetes (De Souza et al., 2015). However, several factors related to feeding regiment have been found to have various effects on ruminant meat quality by playing a crucial role in the determination of meat content (Priolo et al., 2001). The nutrition of cattle and sheep has a considerable impact on the deposition of intramuscular fat that has a remarkable effect on human health (Popova et al., 2008). The content of MUFA in intramuscular fat is substantially higher for grass-fed steers as compared to steers offered grass silage and/or concentrates (Nieto and Ros, 2012). The higher proportion of MUFA to SFA enhances both meat quality and feeding value of animal products (Gamarra et al., 2018). On the other hand, the Stearoyl-CoA Desaturases (*SCD*) gene encodes an enzyme that transforms SFA into MUFA in the adipose tissues of ruminants (Tian et al., 2017) and a positive correlation has been observed between MUFA and *SCD* expression in ruminants (Costa et al., 2013). Although the benefits of grass nutrition on ruminant meat quality and its positive consequences on human health has been described (Pighin et al., 2016), little information is known about ruminant nutrition through what mechanism affects the meat quality. Furthermore, there is a lack of data regarding the contributing effect of biochemical molecules on human health. Therefore, this review aims to describe the main factors that cause variability in several meat-controlling molecules in the ruminants, their consequent effect on ruminant meat, and their eventual effects on human health.

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Effects of saturated fatty acids on human health

The Fatty Acid (FA) composition of dietary lipids and its consequences on meat quality have gained a lot of attention due to its effect on human health (Cho et al., 2010). It has been demonstrated that higher consumption of SFA is associated with diminished insulin sensitivity, hyperglycemia, increasing the risk of metabolic syndromes and cancers such as prostate and breast carcinomas (Khan et al., 2010; Alisson-Silva et al., 2016; Savoini et al., 2016). Furthermore, excessive consumption of ruminant meat, which is a major source of medium-chain SFA and trans FA in the human diet, is considered a risk factor for heart disease (Shingfield et al., 2013). Red meat is also characterized by a particular SFA profile that has been linked to carcinogenesis and CVD (Quiñones et al., 2017). For instance, beef contains several damaging SFAs, such as myristic and palmitic acids that are assumed to be dangerous for the heart, because it raises the serum cholesterol concentrations by four to six folds (de Lemos et al., 2017).

Impacts of polyunsaturated fatty acids and conjugated linoleic acid on human health

The recommended proportion of PUFA to SFA in ruminant meat should be 0.4 or higher (Wood et al., 2003). In this context, changing FA compositions by decreasing concentrations of PUFA and increasing levels of SFA leads to decrease the PUFA: SFA ratio in red blood cell membranes, which may be linked to lower membrane fluidity, as seen in the chronic diseases (Ristić-Medić et al., 2013). On the other hand, the consumption of meat with an imbalanced ratio of n-6:n-3 PUFA can be a risk factor for CVDs, resulting in blood clots and possibly leading to a heart attack (Wood et al., 2003). Furthermore, n-6:n-3 PUFA may also be associated with the progression of carcinogenesis (Azrad et al., 2013). Meanwhile, it has been demonstrated that ruminant meat contains a beneficial ratio of n-6:n-3 PUFA, that is below 4, especially when those have consumed grass-based diets (Pighin et al., 2016). More grazing leads to a higher percentage of omega-3 FA, CLA, vitamin E, β-carotene (Van Elswyk et al., 2014), vitamin A and also a low ratio of n-6:n-3 PUFA in ruminant meats which makes it highly desirable for consumption (Simopoulos, 2016). Beef from pasture-finished steers contains greater levels of n-3 PUFA in comparison to concentrate-finished steers (Pighin et al., 2016). High levels of omega-3 long-chain PUFA (n-3 LC-PUFA) in the diet plays a major role in preventing several diseases, including diabetes, atherosclerosis, and arthritis (Widmann et al., 2011), through inhibition of platelet aggregation, microbial growth (Desbois and Lawlor, 2013), and prevention of the blood clot formation (Phang et al., 2013). Interestingly, a lower incidence of depression, age-related memory loss, and developing Alzheimer's is linked to higher consumption of n-3 LC-PUFA (Wani et al., 2015).

CLA synthesized by microorganisms in the rumen as a byproduct (Arshad et al., 2018), holds considerable benefits for human health. It is believed that the consumption of CLA is beneficial to health because of its ability to increase lean muscle mass while decreasing body fat. It has been suggested that CLA has therapeutic potentials with regard to insulin resistance and hyperlipidemia which are key characeristics of type 2 diabetes (Molony et al., 2004). This relation has recently been explained by the ability of CLA to enhance insulin sensitivity (Cho et al., 2016). Therefore, it was observed that increased CLA has a strong association with anticancer (Peng et al., 2010), anti-adipogenic (Maleki et al., 2015), anti-atherosclerotic properties (De Hartigh, 2019), and cardioprotective effects (Parodi, 2009).

Stearoyl-CoA Desaturases effects on human health

The *SCD* gene product is a major enzyme for controlling intracellular FA composition by stimulating the desaturation of SFA, thereby resulting in the conversion of SFA to MUFA in the adipose tissues of ruminants (Tian et al., 2017). Genetic groups of ruminants have shown significant differences in the activity of the *SCD* gene product (Ivanović et al., 2016). In different organisms, there are five variants of *SCD* genes that are known as, *SCD1–SCD5*, placed at several chromosomal positions (Furqon et al., 2017). Furthermore, the expression of *SCD* in the muscle tissues can be affected by nutrition composition, especially n-3 PUFA contents. The level of *SCD* gene expression plays a key role in terminal adipocytes differentiation as adipogenesis has been found to be greatly induced by *SCD* gene expression (Madsen et al., 2005). This pattern of *SCD*-induced adipocytes differentiation leads to a consequent accumulation of intramuscular fat, which points to the link between the gene expression of *SCD* and increasing FA deposition in the ruminant muscle (Costa et al., 2013). However, hormones and several nutrients including FAs, carbohydrates, and cholesterol, have been recognized as a potent modulator of the *SCD* gene expression. Moreover, the expression of the *SCD* is positively related to elevated CLA and MUFA contents, which entails considerable impacts on human health (Barton et al., 2010).

The impacts of grass-based versus grain-based feeding on the rumen environment

In the ruminant digestive system, the composition of the FAs present in the rumen is affected by the rumen microorganisms and ruminal pH (Kashani, 2015). SFA, like palmitic (C16:0) and stearic (C18:0) acids, pass through the rumen unaltered, while the Unsaturated Fatty Acid (UFA) is subjected to biohydrogenation and converted to SFA to decrease the toxic effects of dietary UFA on the microorganism's growth and production of CLA as a byproduct (Shingfield et al., 2013). LC-PUFA has also been reported to have differential toxicity and inhibitory effects on rumen

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microorganisms (Lourenco et al., 2010). Thus, the conversion of UFA to SFA, or biohydrogenation, in the ruminants represents a major human health issue. It is noteworthy that the high forage proportion in the grass-based feeding causes higher secretion of saliva (Figure 1A), ensuring higher rumen pH (Lee et al., 2016), and thus, strengthening the effect of lipolysis and/or biohydrogenation (Scollan and Enserb, 2003). Grass-feeding increases the content of CLA due to the biohydrogenation of the PUFA linolenic acid in the rumen that has a twofold higher concentration in the digestion of the pasture-fed steers, as compared to corn-fed steers (Smith et al., 2009). Regarding grain-based feeding, the biohydrogenation process was found to be inhibited by a decrease in the ruminal pH and ultimately growth inhibition of the CLA-producing bacteria (Wood et al., 2008) (Figure 1B). The reduction in the pH values is typically linked with this sort of diet, as the presence of concentrated food components reduces lipolysis, which is a fundamental step in biohydrogenation (Menezes et al., 2010). If ruminal biohydrogenation of UFA can be controlled, it may be possible to enhance the quality of ruminant meats via generally increasing UFA, CLA, and n-3 FAs in particular. Most of the alimentary FA are UFAs (oleic acid [C18:1 cis-9]; linolenic acid [C18:3n-3], and linoleic acid [C18:2n-6]) that are converted to SFA (C18:0) in the rumen by biohydrogenation, with a plethora of CLA isomers throughout the process of isomerization (Dewanckele et al., 2018). Therefore, meat products supplied by more isomers of CLA, result in higher CLA concentrations in consumed meat (Silveira et al., 2007).

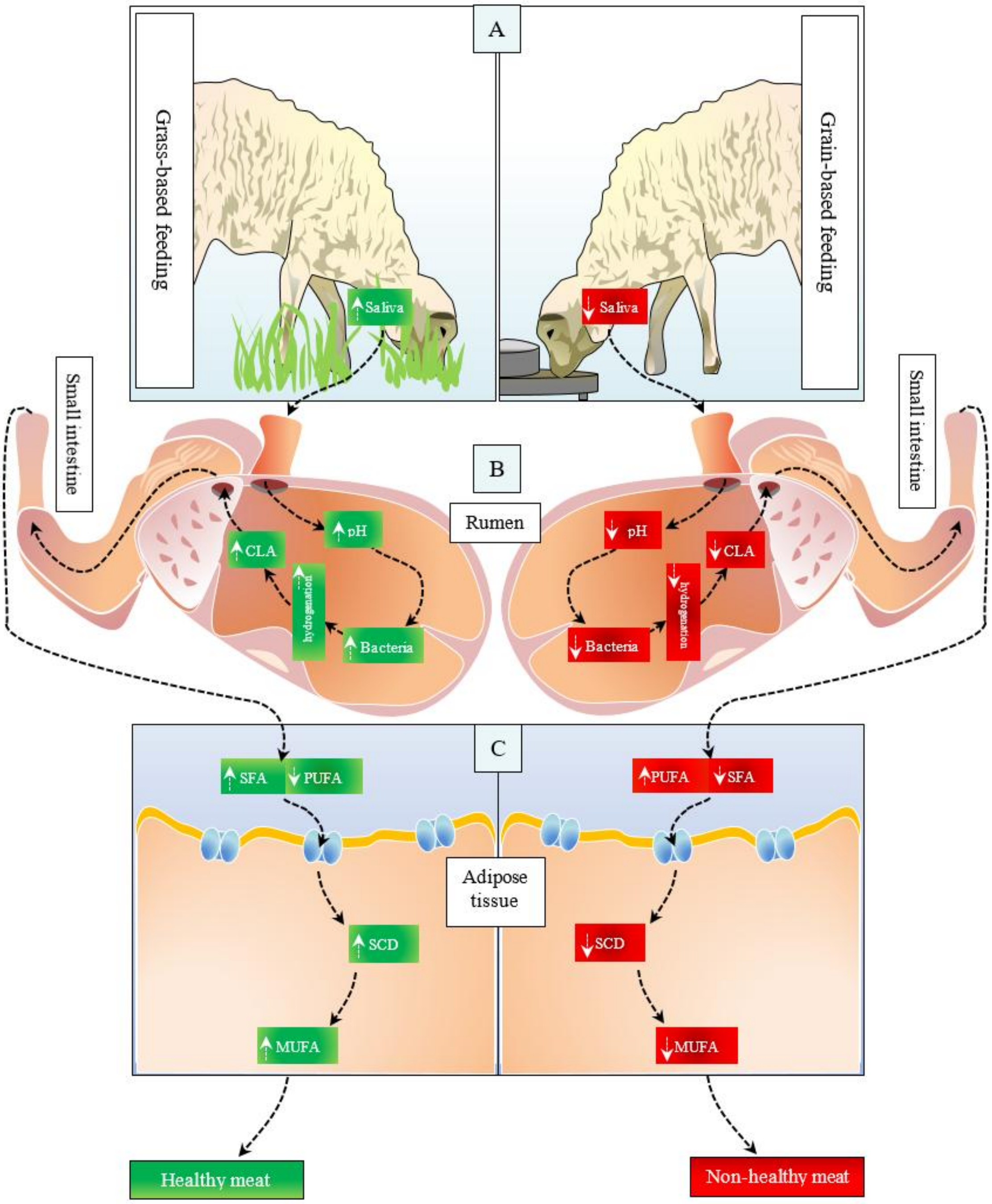

Figure 1. Comparison between grass-based versus grain-based ruminant feeding routes. A, B and C refer to impacts of consumed feed on saliva, rumen, and adipose tissues, respectively.

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The impacts of grass-based versus grain-based feeding on adipose tissue

About 70–80% of FAs were accumulated in the tissues as CLA during the ruminal biohydrogenation of dietary linoleic acid (Lobo et al., 2014). The levels of rumenic acid, the most important CLA isomer, along with arachidonic (C20:4c5) and phytanic acid, are at least three times higher in the muscles of grass-fed animals in comparison to grain-fed animals (Moholisa et al., 2018). The increased concentrations of SFA and decreased concentrations of PUFA in ruminant tissues is due to a higher ruminal pH and consequently higher biohydrogenation rate in the rumen (Hughes, 2011). However, lower gene expression of the *SCD* as a result of an increased level of PUFA has been reported in different animal species and tissues (Conte et al., 2012). Thus, inhibiting the biohydrogenation pathway could increase the levels of PUFA in tissues and lead to a reduction in the gene expression of *SCD* in ruminants (Figure 1C). Moreover, PUFA suppresses the expression of lipogenic genes by inhibiting proteolysis of sterol regulatory element-binding protein 1 in the Golgi apparatus (Jacobs et al., 2013). Therefore, a nutritional regimen that increases PUFA absorption in the muscles will reduce meat quality. A parallel relationship of n-6: n-3 PUFA proportion with levels of *SCD* gene expression and in turn, CLA production in the muscle tissue, was reconfirmed (Ebrahimi et al., 2018).

The higher the expression of the *SCD1* gene in grass-feeding is associated to the elevated converting ratio of MUFAs to SFAs, increased levels of phospholipid membrane composition, fat metabolism, and adiposity (Hilmia et al., 2017). Thus, the high proportion of MUFA to SFA enhances both the quality and feeding value of animal products. The correlation analysis among oleic acid proportion and CLA percentage, with the levels of *SCD* expression in ruminants, appears to have been effective (de Castro et al., 2013). Positive correlations between *SCD* expression and FA content is observed, particularly for total FAs, MUFA, and c9,t11-CLA, while lower *SCD* expression in adipose tissues is detected in Holstein-Friesian cows and mature culled cows when fed with PUFA (Gamarra et al., 2018). Thus, imparting nutrition for animals with PUFA enriched diets results in a lower expression *SCD* gene, which appears to be due to the inhibitory role of PUFA on the promotion of the *SCD* gene in the liver and adipose tissues (Benítez et al., 2017)

CONCLUSION

In conclusion, several factors affect the meat quality of ruminants and lead to sanitation problems for human health. In the last 60 years, reduction in the pasture quality due to a lack of vegetation and the reliance of the farmer to the use of grains for ruminant nutrition caused a decrease in CLA levels, reduced *SCD* activity in tissues, and decreased MUFA (or increased SFA) levels in ruminant meat which are involved in the pathogenesis of several chronic human diseases. Conversely, high expression of the *SCD1* gene in grass-fed ruminants is effective in meat production with a highly favorable quality for the consumers' health.

DECLARATIONS

Competing interests

The authors have declared that no competing interest exists.

Consent to publish

All authors gave their informed consent prior to their inclusion in the study.

Authors' contributions

TM Al-Thuwaini designed the main idea and wrote the review. MBS Al-Shuhaib revised the review and drew the schematic diagram presented in figure 1.

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