Journal of Agricultural Science; Vol. 9, No. 5; 2017
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Effect of Whole Cottonseed or Protected Fat Dietary Additives on Carcass Characteristics and Meat Quality of Beef Cattle: A Review

Erico da Silva Lima[1], Tiago Neves Pereira Valente[2], Roberto de Oliveira Roça[3], Andréia Santos Cezário[4], Wallacy Barbacena Rosa dos Santos[4], Bruno Borges Deminicis[5] & Jeferson Corrêa Ribeiro[4]

[1] Faculdades Metropolitanas Unidas, São Paulo, SP, Brazil

[2] Instituto Federal Goiano, Posse, GO, Brazil

[3] UNESP, Botucatu, SP, Brazil

[4] Instituto Federal Goiano, Morrinhos, GO, Brazil

[5] University of Southern Bahia, Teixeiras de Freitas, BA, Brazil

Correspondence: Tiago Neves Pereira Valente, Instituto Federal Goiano, Campus Posse, GO, Rua Correntina, nº 824, Setor Dom Prudêncio, CEP 73900-000, Brazil. Tel: 55-64-981-097-444. E-mail: tiago.valente@ifgoiano.edu.br

Received: March 1, 2017 Accepted: March 28, 2017 Online Published: April 15, 2017

doi:10.5539/jas.v9n5p175 URL: https://doi.org/10.5539/jas.v9n5p175

The research is financed by Instituto Federal Goiano, Brazil.

Abstract

The use of oil supplies in feed increases the energy density of the diet and has the potential to enhance both animal performance and meat quality. Whole cottonseed is an oilseed that has a high concentration of oil and is especially rich in unsaturated fatty acids such as linoleic acid. Whole cottonseed is considered as an excellent alternative addition to ruminant feed. Protected lipids are composed of industry-based fatty acids. In the feedlot, protected lipids are used in conjunction with calcium and, in certain cases, their addition has been seen to augment meat quality in terms of essential fatty acid concentrations. This review discusses and debates the use of the whole cottonseed as well as protected lipids (calcium salts of fatty acids) as dietary additives to ruminant feed and diet, and also its impact on meat quality. The whole cottonseed and or protected lipids are viable feedlot alternatives for use in feedlot when it is desired to reduce the amount of starch in animal diet without compromising the performance. The addition of the whole cottonseed or protected lipid in diet is not affect pH values in meat. The whole cottonseed does not contribute to the improvement of tenderness of the meat. The proportion mean of Desirable fatty acids in meat in the comparative study were: as pentadecanoic acid (C15:1 = 0.29%), palmitoleic acid (C16:1 = 4.26%), heptadecanoic acid (C17:1 = 0.07%), oleic acid (C18:1n9c = 37.32%), γ-linolenic acid (0.94%) and α-linolenic acid (1.04%), elaidic acid (C18:1n9t = 0.50%), eicosatrienoic acid (C20:3n3 = 0.03%), eicosapentaenoic acid (C20:5n3 = 0.04%), erucic acid (C22:1n9 = 0.89%), docosadienoic acid (C22:2 = 0.04%) and stearic acid (C18:0 = 21.53%). The addition the cottonseed or protected lipid in diet does not affect fatty acids profiles the desirable fatty acids in meat.

Keywords: beef quality, biohydrogenation, fatty acid profile

1. Introduction

In an attempt to reduce the costs incurred for in the process of animal meat production, farmers are increasingly seeking alternative feed additives, which, along with being cheaper to source and use, feedstuffs to reduce costs in animal production. In addition, these feeds must are also required to have qualities that are desired by the farmer for a satisfactory animal performance. An alternative that is attracting a great deal of interest is the use of oilseeds as feed additives (Juaréz et al., 2011, 2012). Oil seeds are known to have a high percentage (75% on average) of unsaturated fats (examples: oleic, linoleic, and linolenic acids) that are liquids at ambient temperature. They also have the added advantage of exerting an inhibitory effect on the growth of gram-positive bacteria (Malik et al., 2015; Valente et al., 2016, 2017). Excessive amounts of dietary lipids are known to have a negative effect on fiber digestion in the rumen, which may influence the quality of meat (Lima et al., 2015a). To minimize the negative effect of dietary lipids on the fiber-digesting microorganisms, in the rumen, would be to supply the lipid additive in a form that is protected from ruminal degradation (Jenkins et al., 2008; Messana et al., 2013). Unfortunately, very limited number of studies in the literature discusses the use of such protected lipids and their impact on animal performance and meat quality characteristics.

2. Lipid in Diet

Fats are considered as an important component of the meat production system largely because production efficiency, precocity, carcass fat cover, yield cuts, tenderness, and succulence of the meat are related to the quantity and to the site of fat deposition (Andrae et al., 2001; Veracini et al., 2013). The quality of the fat deposit is evaluated based on factors such as fat color, cooking yield, shear force, sensorial traits and chemical and fatty acid composition (Andrade et al., 2014; Domingues et al., 2015). Fat deposits can contain composed of two types of fatty acids: (a) UFAs, or unsaturated fatty acids that possess one or more double bonds in their chemical structure, and (b) saturated fatty acids that contain are composed of only single bonds in the molecule (Lehninger et al., 2000; Berg et al., 2006; Nelson et al., 2008). The state of saturation or unsaturation is an important characteristic chemical and the nutritional (Jenkins, 1993; Van Soest, 1994). While formulating diets for ruminants, it is essential that they are more energetic (Mir et al., 2003). Lipid supplements are frequently included in ruminant diets in an attempt to increase the energy density of the feed while simultaneously increasing the nutrient utilization, and the meat production, allowing for the easy management of the fatty acid composition of in the diet (Palmquist et al., 1994; Mangrum et al., 2016). In non-ruminant animals, the digestion and absorption of dietary lipids occurs in the small intestine. In the case of ruminants, however, this process is undertaken by the microorganisms residing in the ambient rumen-reticule. Thus, in the specific case of ruminants, the metabolism of lipids, including processes such as hydrolysis and hydrogenation of lipids contained in the feed or the de novo synthesis of cellular lipids required by the microorganisms, occurs in the rumen (Van Soest, 1994). The relatively low percentage of UFA in the fat content of ruminants is known to be associated with ruminal metabolism, endogenous fatty acid and triacylglycerol biosynthesis. UFAs such as linoleic and linolenic acids must be extracted from the dietary source. When these fatty acids are ingested by the ruminant, the rumen microorganisms hydrolyze lipids and convert UFAs into saturated forms by a process called hydrogenation (Or-Rashid et al., 2011). Thus, unlike monogastric animals, supplying ruminants with a fat diet containing predominantly UFAs does not significantly increase the content of these unsaturated fatty acids in the adipose tissues. From this, concluded that lipids contained in the tissues of ruminants are more saturated than those contained in the non-ruminant animals.

3. Lipid Level in the Diet

A high concentration of dietary fat can cause problems in the absorption of nutrients largely because fatty acids reduce ruminal pH and ocurrs a change in microorganism (Valente et al., 2016). Fat also reduces the digestibility of forage; long chain fatty acids are known to exert a toxic effect on cellulolytic bacteria (Nagaraja et al., 1997; Suen et al., 2011). The presence of a higher fat content in the diet causes a decrease in fiber digestibility (Palmquist, 1994; Allen, 2000; Russell & Strobel, 2005). The impact of this phenomenon manifests itself in largely two ways: (a) a decrease in total tract digestibility causes a downstream decrease in the total energy value of the fiber; and, (b) the greater retention of fiber in the rumen limits dry matter intake (DMI) resulting in a decrease of the total energy intake by the animal. Earlier previously published studies have established that a greater than 7% fat content in the dry matter (DM) of the diet limits the degradation of dietary fiber by the animals (Medeiros, 2002; Valente et al., 2015). Additionally, it is also known that diets that contain more than 5% lipid in DM affect the acceptability of the concentrate. The use of calcium (calcium soap) helps to reduce the negative effects of dietary fats on fiber digestion in diets that contain more than 40% forage (forage: concentrate ratio). Calcium exerts its action by remaining relatively inert in the normal pH conditions prevalent in the rumen but dissociating completely in the acidic conditions of the abomasum (Jenkins & Palmquist, 1984). The incorporation of these products suggests that the lipids that escape ruminal fermentation increase the energy density of the diet without affecting the use of forage. Thus, it can be deduced that adjusting microbial biohydrogenation by regulating the absorption of certain fatty acids may aid in improving the performance while reducing meat fat saturation (Jenkins, 1993; Smith et al., 2009).

4. Use of Protected Lipids in Cattle Feed

The major problems encountered while feeding cattle in feedlots is the occurrence of metabolic disorders caused when large amounts of carbohydrates during the high ruminal fermentation process are present in the form of starch (Harmon et al., 2004; Enemark, 2008; Calsamiglia et al., 2008). An increase in the supply of lipids has the potential to serve as an alternative so as to reduce the inclusion of starch while maintaining the same level of energy in the diet (Russell, 2002; Krause et al., 2014). However, excessive dietary lipids have a negative effect on fiber digestion in the rumen which in turn may influence the quality of meat. The negative effect of lipid on the microbiota responsible for digesting fiber in the rumen can be circumvented over come by the dietary inclusion of lipid protected from ruminal biohydrogenation (Aferri et al., 2005). It is known that the inclusion of lipids at concentrations up to 4.6% of the diet does not affect the animal performance or carcass characteristics (Bartle et al., 1994). For this reason, currently at present, the inclusion of lipids in ruminant diets is limited to a maximum of 5% of the total DM with the understanding that beyond this concentration, the microorganisms residing in the rumen can not efficiently execute physiological mechanisms required for the digestion of carbohydrates or proteins. The inclusion of energy feeds in the diet of feedlot cattle is the best possible way for achieving higher weight gains and for allowing adequate carcass dressing. There are a number of possible fat sources that can be used in ruminant diets. These include fats such as soybean oil (French et al., 2000; Vargas et al., 2002), commercially protected lipid (Warren et al., 2008), and grain oil (Valinote et al., 2005). However, there is no common underlying factor that can predict the effect of the presence of these energy sources in the diet of feedlot cattle. The use of whole cottonseed or protected fat was not observed to cause any deleterious effect on the proportion of short-chain fatty acids present in the rumen of steers fed with on an 80% concentrate diet containing 9.6% of ether extract. However, that there was a reduction observed in the for NDF degradability (Valinote et al., 2006). The uses of calcium salts are known to have no impact on the chemical biohydrogenation process of in the rumen (Duckett, 2017). An alternative is to supplement the diet with oil seeds because as a result of the physical protection, the biohydrogenation in the rumen also decreases. Klusmeyer and Clark (1991) have suggested that in the specific case of biohydrogenation of UFA C18:0, the partial protection conferred by the presence of calcium salts can be quantified at approximately 33%. From this, it can be inferred that the inclusion of fats in the diet of ruminants exerts a beneficial effect. Lower saturated fatty acids (SFA) percentages were observed in the lipids of steers whose diets had been were supplemented with 5% rapeseed or sunflower oil. This reduction in the saturated fat content can be accounted ascribed to for by the decreased palmitic acid content of both diets and the increased eicosenoic and erucic acid deposition in the steers fed on rapeseed oil supplement. Eicosenoic and erucic acids are found in high levels in rapeseed oil and the presence of these lipids in the tissue is indicative of the fact that they can escape the process of rumen biohydrogenation (Lima et al., 2015a).

5. Meat Characteristics

Beef have a high biological value beyond provides several other nutrients such as essential amino acids, B vitamins, iron, zinc, etc. It is an indispensable and essential part of a healthy diet. Factors that restrict meat consumption by the general population are its high cost and the association of its intake with cardiovascular problems and obesity (Barendse, 2014). Meat that has a low lipid content, lower levels of SFA and calories, and a higher content of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) will be perceived by the consumer as a food that promotes a standard healthy life while simultaneously preventing the development of cardiovascular disease (Stipanuk, 2000; Teixeira, 2003). Amongst the lipids found in animal-tissue based lipids, cholesterol is the component that gets maximal emphasis as a major causative agent of both atherosclerosis as well as heart disease.

Three crucial factors can impact affect the quality and composition of the meat produced. These are: (a) the feedstuffs used for feeding the animal; (b) race or genetic cross of the animal; and, (c) the age at which the animal is slaughtered. The quality of the meat is a major factor used for marketing the product (De La Torre et al., 2006). Beef that does not meet with a high standard of quality competes with similar animal-based products from other species such as swine and poultry. Lipids, based upon their composition, can be employed in feeding beef cattle for the generation of animal products having good and desirable nutritional characteristics (Schmid et al., 2006).

6. Animal Performance

The ingredients used in animal diets, are strongly associated with animal performance. Thus, it can be said that the ideal feed should be economically viable and should promote desirable weight gain while simultaneously reducing the cost of animal production. The use of whole cottonseed (15% of dietary DM) no influence on the daily weight gain of Holstein steers in feedlot when compared to steers whose diet did not contain this source of fat (Jorge et al., 2009). Second Costa et al. (2013) evaluated different concentrations of cottonseed (0, 14, 27, and 34% of DM) and concluded that animal performance decreases as the proportion of cottonseed in diet increases. This negative impact on animal performance can be attributed to the reduction in the digestibility factor of NDF, which occurs when the fat content of the diet is high (Jenkins, 1993). Interestingly, Aferri et al. (2005) observed no difference in the performance of feedlot steers when a cottonseed diet (21% DM) was compared with a diet containing calcium salts of fatty acids (SCFA) (5% DM). The addition of SCFA to the diet of cattle did not present with a significant change in the average daily weight gain of the animals. The SCFA can be used as an alternative to increase the energy density of diet for feedlot animals (Silva et al., 2009).

7. Carcass Characteristics

Feed has the potential to exert a significant influence on the percentage of fat in the carcass and muscle (Al-Jammas et al., 2016). Carcass yield of bovine animals is influenced by intrinsic (breed, sex, body condition, and weight at slaughter) extrinsic factors (feed management and finishing system). In order to obtains a good and productive results, there should exist a strong correlation between cold carcass weight and live weight before slaughter. This is an important indicator of consumer meat availability (Lima et al., 2015b).

The measurement of the eye-loin area in *M. longissimus thoracis* is directly related to the total muscle present in the carcass while the thickness of the subcutaneous fat layer is directly related to the total carcass fat and indirectly related to the total amount of muscle. Thus, a greater accumulation of fat results in a lower proportion of muscle and reduced number of lean cuts from the off the carcass (Toldr, 2010). A minimal amount of subcutaneous fat in the carcass is needed to ensure optimum quality of meat (Tatum et al., 2000). Donicht (2011) have hypothesized that subcutaneous fat acts as a thermal insulator and protects the carcass from cold shortening (a process that occurs during cooling of carcasses in slaughterhouses). A study conducted by Muller et al. (2005) on finished heifers fed with on diets containing flaxseed, protected fat with calcium and other non-added fat source reported that the diets failed to significantly impact affect carcass yield. A significant proportion of fats undergo esterification with glycerol in order to form triglycerides. Hence, the oils and fats that are commonly used are a relatively complex mixtures of triacylglycerols. Fatty acids represent about 95% of the molecular weight of triacylglycerols. It is to be noted that fatty acids that are derived in part from animal fats differ from other types of fats on the basis of the size of the carbon chain as well as the type of bond that bind them (Barendse, 2014).

Isomerism around the double bond determines the cis (on the same plane radicals) or trans (on opposite planes radicals) nature of the bond. Most naturally occurring fatty acids in mammals are in the cis configuration, but in ruminants, biohydrogenation can convert some of the acids into the trans form. Unsaturated fatty acids are known to be chemically unstable with a relatively lower melting point. As a result of this, they are unable to pass through bacterial membranes. Hence, to enable the degradation of lipids in the rumen, unsaturated fatty acids are hydrogenated by the hydrogenase enzymes in a process known as biohydrogenation (Berg et al., 2006; Nelson et al., 2008). This process also explains why the fatty acid profile of beef meat is more saturated even when cattle are fed on the feeds that are rich in unsaturated fats (Barletta et al., 2016). However, that oil contained in seeds such as the whole cottonseed is protected from ruminal degradation. Another way by which lipids can be protected, despite the hydrogenation of unsaturated fatty acids by rumen microorganisms, is by supplying it to the cattle in the insoluble form, *i.e.*, as salts of calcium bound fatty acids (Ca soap). Ruminants and monogastric animals require essential fatty acids (EFAs) that they are incapable of synthesizing themselves (Barendse, 2014). Such the essential fatty acids, examples of which include linoleic and linolenic acids, are usually derived by the animal from the dietary sources. Linoleic acid is especially significant because it is the source for the synthesis of arachidonic acid. On the other hand, linoleic acid is the precursor molecule for the synthesis of several polyunsaturated fatty acids of special nutritional value (Jenkins, 1993). Among the EFAs that are commonly present in animal fat, linoleic (C18:3) and arachidonic (C20:4) acids are regarded as essential for human health and nutrition. The essential fatty acids are important components as constituents of the cell membrane and play crucial roles in, the absorption of fatty acids and in reproductive functions (Mattos, 2000).

Intramuscular beef fat is composed of about 44% saturated fatty acids, 5% odd-chain, 45% monounsaturated, and 5% polyunsaturated fatty acids. Although beef is popularly associated with a high cholesterol content, it is well established that polyunsaturated and monounsaturated fatty acids play a crucial role in reducing blood cholesterol. Stearic acid, another type of fatty acid, is also known to contribute towards reducing serum cholesterol in humans. It works primarily by decreasing cholesterol absorption while increasing the excretion of endogenous cholesterol (Duckett, 2017).

In recent years, conjugated linoleic acids (CLA) have been the focus of much speculation and research in the animal production area largely because of the discovery that they are anticarcinogenic in nature (Schneider et al., 2000). A variety of other beneficial health effects associated with CLA and omega-3 class fatty acids have been reported by M. A. McGuire and M. K. McGuire (2010). These factors have stimulated the research to into enabling modification of the fatty acid profile of animal meat improving the nutritional value of food.

8. Biohydrogenation

Polyunsaturated fatty acids such as C18:2 have a diene double bond configuration present at the cis-9-9 and cis-1-12 positions. The first step in the biohydrogenation process is an isomerization reaction that converts the cis-12 double bond of unsaturated fatty acids into a trans-11 isomer. This isomerase is not functional unless the fatty acid substrate has a free carboxyl group. The requirement for a free carboxyl group establishes that lipolysis is a prerequisite for the biohydrogenation process (Figure 1). Once the isomerase forms the trans-11 bond, another enzyme, a microbial reductase, hydrogenates the cis-9 bond. The last step of the biohydrogenation process is the reduction of vaccenic acid to stearic acid (C18:0) (Harfoot & Hazlewood, 1988; Nelson et al., 2008). The extent to which trans-11 C18:1 is hydrogenated hydrogenated to C18:0 depends on the conditions that are prevalent in the rumen. Complete hydrogenation to stearic acid is promoted by the presence of ruminal fluid and feed particles and is inhibited irreversibly by the presence of large amounts of linoleic acid (Jenkins, 1993; Berg et al., 2006).

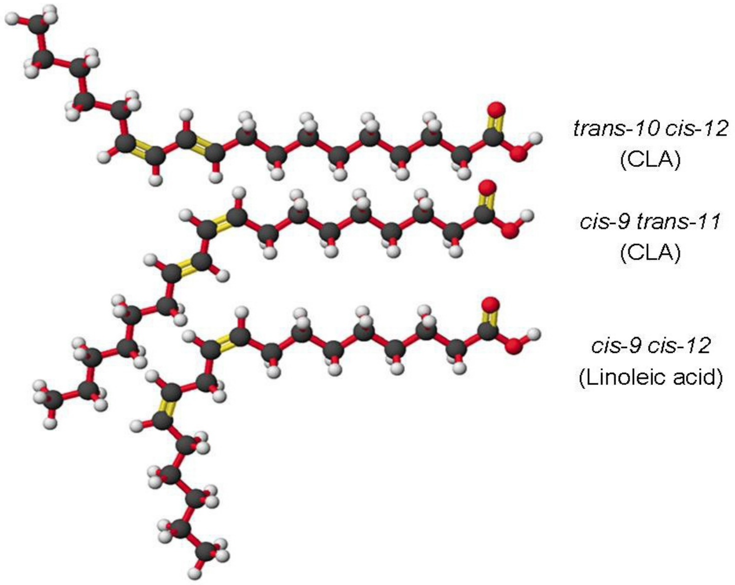

Figure 1. Structural representation of isomers of CLA and its precursor

Source: Conjugated Linoleic Acid For Weight Loss, 2017.

Hydrogenation of C18:1 trans-11 appears to be the rate-limiting step of the biohydrogenation process. As a result of this, the penultimate intermediate accumulates in the rumen and becomes available for absorption (Bauman et al., 1999). This process is important for another endogenous form of CLA synthesis that involves the delta-9 desaturase enzyme, which uses trans-11 C18:1 as a substrate. This enzyme acts by introducing unsaturation at the C9 position of vaccenic acid to form cis-9, trans-11 CLA (Griinari et al., 2000; Mosley et al., 2006).

CLA present in the fat of ruminant-based meat from two sources: (a) the partial biohydrogenation of linoleic acid in the rumen, and (b) endogenous synthesis in the adipose tissue (Figure 2). Between these two processes, endogenous synthesis is more significant than the ruminal secretion of CLA (Castagnino et al., 2015). The increased vaccenic acid content is important for both cattle (Griinari et al., 2000) and humans (Adlof et al., 2000) as both have the capacity to synthesize CLA. Nutritional manipulation of the rumen is a strategy that aims to change the content and composition of lipids in ruminant-based meat (Demeyer & Doreau, 1999).

Andrae et al. (2001) compared diets supplemented with corn oil and the conclusion that it leads to an improvement in the deposition of intramuscular lipids and increases the concentration of unsaturated fatty acids in case of *M. longissimus thoracis* beef cattle finishing. A study conducted by Pires et al. (2008) aimed to determine the effects of diet on the PUFA content of animal meat. To this effect the authors supplemented the diet of Nellore cattle in feedlot with calcium salts of soybean fatty acids. The results of the study led the authors to conclude indicated that the animals fed on with protected fat (5.24%) had a greater PUFA content in meat as compared to meat from animals fed on the feed without protected fat (4.21%). Andrade et al. (2014) found different results for PUFA content in meat with the diets with and without protected lipids in the feedlot. Contrarily, Costa et al. (2013) reported that diets with different concentrations of the whole cottonseed did not affect the concentration of conjugated linoleic acid, SFA or total UFA in meat.

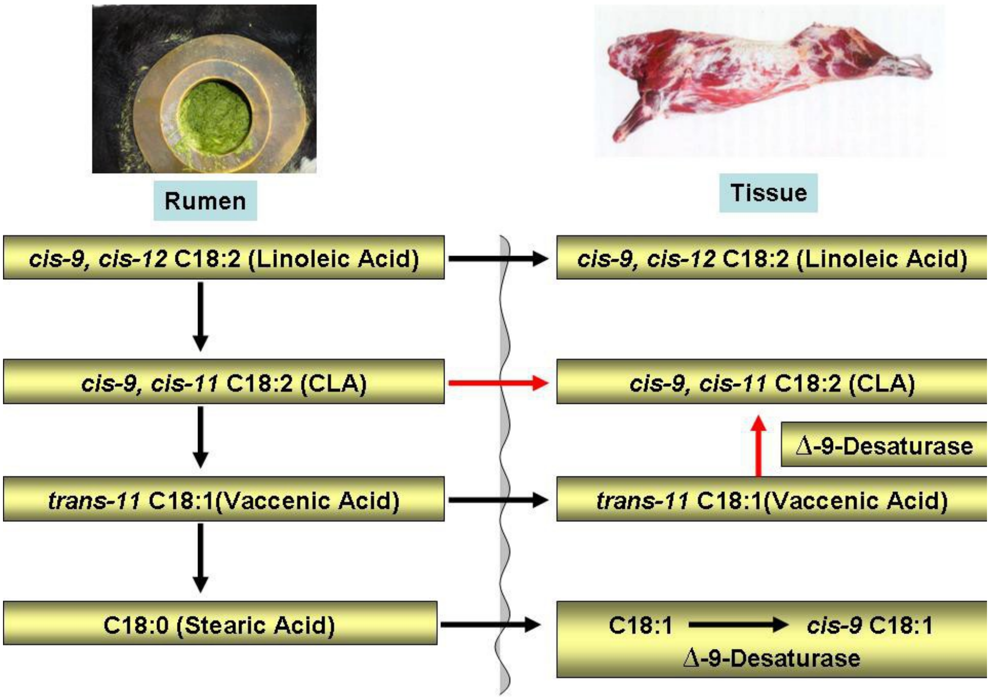

Figure 2. Formation of CLA in the rumen and tissues

Several factors are known to affect the extent of biohydrogenation. These include ruminal pH, the amount, and source of fat in the diet, the type and proportion of forage in the diet, the presence of ionophores and shape protection of dietary lipids (Chilliard et al., 2000, 2001; Shingfield et al., 2005).

9. Centesimal Composition of Meat

A study conducted by Lima et al. (2015b) where in the authors analyzed the centesimal composition of the carcass and, found that the dietary inclusion of CS or PL did not have a significant impact on the average moisture content of the *M. longissimus thoracis* (73.48%). Similar results were observed by Costa et al. (2013) and Andrade et al. (2014) determined that the average moisture content as 75.14% and 76.10%, respectively. These authors also did not detect any significant differences between the treatments for meat protein or ash. However, Costa et al. (2013) noted that the addition of LP in the diet increased the percentage of intramuscular fat ($P < 0.05$). Interestingly, ether extract percentage of muscle was seen to decrease linearly with the increase in the amount of CS in the diet of cattle in the feedlot. These results are strongly indicative of the fact that LP is more efficient in passing through the rumen so as to be absorbed in the small intestine and subsequently incorporated into the muscle (Putrino, 2006; Lima et al., 2016).

10. Characteristics Aging Times of Meat and Subcutaneous Fat Color

Different factors can influence the shear force. The texture of the meat can be influenced by age, weight for slaughtering animals. Second studies of Shackelford et al. (1994) for cattle *Bos taurus indicus* usually have higher value of the shear force. However Aferri et al. (2005) and Andrade et al. (2014), the difference in shear force when cattle were fed cottonseed or PL not been observed.

For Watanabe et al. (2015) compounds losses include free amino acids, peptides, reducing sugars, vitamins and lipids when meat cooking. Several authors concluded that cooking yield of cattle fed lipid sources showed the differences to the loss by cooking to feed cattle with whole cottonseed or protected lipid (Costa et al., 2013; Andrade et al., 2014).

In studies were observed with brightness the meat to improve beef color. For brightness L*, intensity the red a*, intensity of yellow b* the muscle initial red color intensity increased whereas both mitochondrial oxygen consumption and color stability decreased (Suman et al., 2014). The decrease in mitochondrial oxygen consumption associated with longer aging times will increase initial color intensity (Mancini & Ramanathan, 2014).

11. pH Value

Compare the cattle fed diets with whole cottonseed or protected fat (Lima et al., 2015a), no differences were found after 24 h analysis of pH *post-mortem* of the mean value for this variable was 5.59. Final pH values was in the normal range (5.4 to 5.8) for beef cattle (Mach et al., 2006). In the same way as, findings similar to those of the present study were reported by Aferri et al. (2005), Pesce, 2008, Costa et al. (2013) and Oliveira et al. (2011), no found any differences between the diets containing or not the lipid source, remain pH in the normal range. Second Bee et al. (2006) unlikely to occur changes in pH with the addition of lipid in the diet.

Several stress factors have been reported as responsible for glycogen depletion: duration of transport and handling from farm to slaughterhouse, temperament, buffering capacity of muscle, climatic factors, live weight, gender, and others (King et al., 2006).

12. Taste, Flavor, Juiciness and Tenderness

Factors that affect meat flavor can be divided into two categories: (a) the water-soluble compounds (thiamine, glycogen, nucleotides, sugars, amino acids, amines), and (b) the lipid fraction (Fadel et al., 2015). The main chemical reactions that occur during the process of cooking of meat are the Maillard reaction (between sugars and amino acids) and the thiamine and lipid degradation reactions. Both of these reactions produce volatile compounds as end products. According to Gustone (2006), there are three major types of interactions occur between fat and flavor. Firstly, fat absorbs hydrophobic flavor compounds generated both while the animal is living as well as those formed when the meat are cooking. Secondly, fats are the precursor molecule for the synthesis of a large number of compounds responsible for augmenting flavor (aldehyde, ketones, volatile fatty acids, secondary alcohols) as well as smells, both desirable and well as undesirable (flavor, rancidity, and burned flesh). And thirdly, it has been reported that the phospholipids, as represented by structural components that have a high concentration of polyunsaturated fatty acids containing at least three or more double bonds, are the main compounds responsible for the obvious changes as far as meat quality is concerned in the quality of the meat. Upon heating, Are represented by structural components having in its composition, the high concentration of polyunsaturated fatty acids, particularly with three or more double bonds, such as these phospholipids, such as arachidonic acid (C20:4); these, release chemical products by heating that participate in the Maillard reaction (Hui, 2012). Although arachidonic acid participating contributes significantly to in the desirable taste of boiled beef, it arachidonic acid is extremely more susceptible to oxidation during the heating process and can give rise to a the associated disagreeable taste (Mottram, 1998). It is observed that increasing the lipid level in the cattle diet can lead to a corresponding increase in the UFAs content of meat. This may result in potential problems with respect to flavor (taste + smell) as PUFA predisposes the meat to rancidity (Nurnberg et al., 2005). As a result of its susceptibility to oxidation, PUFA correlates negatively with flavor notes in sensory panels. Linolenic acid (C18:3) is known to be twice as susceptible to oxidation as compared to linoleic acid (C18:2) (Lima et al., 2015b).

Along with taste and smell, juiciness and tenderness are also important attributes used to describe meat. Consumer preference is biased towards meat that is tenderer. During the chewing process, fat is released, which stimulates salivation and increases the perception of both juiciness and tenderness. Hence, as a result of the lubricating effect of fat, meat with an increased content of fat is perceived as juicier and tenderer (Gustone, 2006). Every change in cattle feed has the potential to cause downstream changes in the composition and sensory characteristics of the meat. This is why it is very important to conduct a sensory analysis of the final product so as to gauge consumer acceptance. The inclusion of PL (calcium salt of fatty acids) in the diet was not observed to alter the sensory properties of meat derived from Angus × Nellore bulls in the feedlot (Andrade et al., 2014). However, Costa et al. (2013) conducted a study where in they used cottonseed as a source of fat and observed that both flavor and taste of meat were adversely altered when cottonseed concentrations exceeded 14.35% and 27.51% of the diet, respectively. Shibuya (2004) evaluated taste and juiciness of meat derived from crossbred steers (Simmental × Brangus) who were fed on either CS (21% in DM) or PL (5% in DM) and concluded that there are no significant. Despite, several studies have reported that an inclusion of LP in the diet of feedlot cattle leads to changes in the aroma intensity and induces the presence of strange aroma or taste and also affects the juiciness (Patil et al., 1993; Hopkins et al., 2006; Ibrahim et al., 2008).

13. Effect of Whole Cottonseed or PL on the Fatty Acid Profile of Meat

Diet that contains high concentrations of fat, either partially or completely protected from microbial action in the rumen, can cause changes in the fatty acid profile and may lead to an increase in the intramuscular fat deposition (Souza et al., 2007; Fiorentini et al., 2012; Andrade et al., 2014). The higher concentrations of C18:0 that were observed in the meat of the animals fed with on 11.50% CS were very close to those that were had been previously reported by Costa et al. (2013) used 14.35% CS. According to Silva et al. (2009), the addition of

SCAG to the diet of cattle leads to an increase in the percentage of C18:0 present in meat. When consumed by humans, stearic acid is transformed into oleic acid (monounsaturated), a fatty acid that does not carry any cardiovascular risks (Barendse, 2014).

Andrade et al. (2014) have reported that differences in treatments do not translate into differences in the meat FA profile. Contrarily Fiorentini (2009) and Souza et al. (2007) have found that the use of different sources of fat in the diet does cause a certain degree of modification to the FA profile of meat. Regardless of whether the diet contained whole cottonseed or PL, it was found that fat deposits had a higher proportion of oleic acid (C18:1 cis-9) followed by palmitic (C16:0) and stearic acids (C18:0).

According to Bee et al. (2006) analyzed fatty acids in cases where in PL was used as a feed ingredient, oleic acid was the dominant fatty acid in intramuscular fat depositions. Second Lima et al. (2015a) the proportion of other fatty acids were as follows: SFA (53.53%), MUFA (42.59%) and PUFA (2.96%), no differences were found when compared fatty acid profile in the meat, for CS or PL (Table 1).

Table 1. Proportion of the fatty acid profile in the meat for the different treatments

Fatty acid profile	Diets		
	2,50% CS	11,50% CS	PL
C8:0 - (Caprylic)	0,03	0,03	0,00
C11:0 - (Undecanoic)	0,29	0,46	0,25
C12:0 - (Lauric)	0,11	0,14	0,07
C14:0 - (Myristic)	5,09	5,24	4,91
C15:0 - (Pentadecanoic)	0,46	0,49	0,45
C15:1 - (Pentadecenoic)	0,32	0,25	0,31
C16:0 - (Palmitic)	28,40	29,47	28,81
C16:1 - (Palmitoleic)	4,65	3,33	4,80
C17:0 - (Margaric)	1,51	1,21	1,48
C17:1 - (Heptadecenoic)	0,09	0,00	0,12
C18:0 - (Stearic)	22,73	20,70	21,17
C18:1n9c - (Oleic)	35,87	37,76	38,33
C18:1n9t - (Elaidic)	0,57	0,49	0,43
C20:0 - (Araquídic)	0,48	0,36	0,23
C20:2 - (Eicosadienoic)	0,35	0,42	0,36
C20:3n3 - (Eicosatrienoic)	0,05	0,02	0,01
C20:5n3- (Eicosapentaenoic)	0,07	0,04	0,00
C22:1n9 - (Erucic)	0.92	0,80	0.95
C22:2 - (Docosadienoic)	0,08	0,03	0,02
Non-identifiable	2,13	2,07	2,53

Note. t - trans; c - cis; n = position of the double bonds; CS = cottonseed; PL = protected lipid (Lima et al., 2015a).

A study by Costa et al. (2013), determined the following proportion of fatty acids: SFA (27.83%), MUFA (16.02%) and PUFA (55.9%), oleic acid (15.45%), and linolenic acid (55.72%). Silva et al. (2009) concluded that the fatty acid composition of meat exhibits little or no effect upon the inclusion of CSFA (4% of DM) in the diets of the animals. Unsaturated fatty acids such as palmitoleic acid (C16:1), eicosapentaenoic C20:5(n-3) and omega-3 eicosatrienoic C20:3(n-3) acids are important components of the human diet as they help in preventing the development of cardiovascular diseases. All SFAs are known to be hypercholesterolemic in nature with the most undesirable SFAs being myristic acid (C14:0) and palmitic acid (C16:0). Stearic acid (C18:0), which makes up approximately 1/3 of the SFA content, is considered to have beneficial properties. Bertrand et al. (2005) noted no change in the content of C14:0 upon the addition of PL to diet vegetable oils that are produced as a result hydrogenation are known to contain high concentrations of elaidic acid (C18:1 trans-9) which is also implicated in hypercholesterolemia (Wills et al., 1998; Sander, 2000).

Feijó et al. (2016) compared Nellore and Brangus bulls with respect to the fatty acid composition of their intramuscular lipid deposits and arrived at the conclusion that the fat from Brangus bulls has a higher content of palmitic acid (C16:0; 17.7% vs. 15.3% $P < 0.05$), stearic acid (C18:0; 11.9% vs. 8.9% $P < 0.05$), oleic acid (C18:1cis-9; 28.1% and 23.3% $P < 0.05$) as well as elaidic acid (C18:1 trans-9; 0.15% and 0.12%, $P < 0.05$). The bulls y also had were also found to contain 20% and 18% greater amounts of both SFA and MUFA ($P < 0.05$). When fed with on a high fat diet (6.4% ether extract), increased the amount of stearic acid present increased (C18:0; 11.5% vs. 9.3% $P < 0.05$). The content of rumenic acid (C18:2 cis-9 trans-11, mean 0.19%), on the other hand, remained unaffected by both genetic group as well as and diet (Fiorentini, 2009). The differences observed in the fatty acid content of Brangus and Nellore bulls are in accordance with the higher marbling effect that is seen in the former. The fatty acid profile of cattle fed with on cottonseed may have been subject to extensive biohydrogenation as is suggested by the higher levels of stearic acid found in the samples taken from animals fed on a high fat diet. The dietary inclusion of PLs derived from soybean oil (rumen-protected fat) is not recommended as a method to for improving the lipid profile of subcutaneous fat meat and meat subcutaneous fat of derived from Nellore cattle (Putrino, 2006; Carvalho et al., 2016).

14. Conclusion

Livestock is fundamental evaluation of this review evaluated the viability of various oil sources as possible feed additives ingredients in feed for cattle and analyzed their efficacy with respect to increasing the quality of, aiming at a quality meat.

The factors that are essential for predicting animal performance and meat quality are as follows: the fatty acid profile of the oil source that is to be used as cattle feed additive adopted, the form of ruminal protection that is available, and the ether extract content of the proposed supplemented diet are essential to predict animal performance and meat quality.

The whole cottonseed and or protected lipids are viable feedlot alternatives for use in feedlot when it is desired to reduce the amount of starch in animal diet without compromising the performance.

Most of the published studies have been inconclusive in proving whether the use of protected lipid increases the content of essential fatty acids in animal meat.

Most of the sensory characteristics of meat are not affected by the use of diets supplemented with protected lipid or cottonseed.

References

Adlof, R. O., Druval, S., & Emken, E. A. (2000). Biosynthesis of conjugated linoleic acid in humans. *Lipids, 35*, 131-135. https://doi.org/10.1007/BF02664761

Aferri, G., Leme, P. R, Silva, S., Putrino, S. M., & Pereira A. S. C. (2005). Performance and carcass characteristics of steers fed with diets containing different sources of lipids. *Braz. J. Anim. Sci., 34*, 1651-1658.

Al-Jammas, M., Agabriel, J., Vernet, J., & Ortigues-Marty, I. (2016). The chemical composition of carcasses can be predicted from proxy traits in finishing male beef cattle: A meta-analysis. *Meat Science, 119*, 174-184. https://doi.org/10.1016/j.meatsci.2016.04.029

Andrade, E. N., Polizel Neto, A., Roça, R. O., Faria, M. H., Resende, F. D, Siqueira, G. R., & Pinheiro, R. S. B. (2014). Beef quality of young Angus × Nellore cattle supplemented with rumen-protected lipids during rearing and fatting periods. *Meat Sci., 98*, 591-598. https://doi.org/10.1016/j.meatsci.2014.05.028

Andrae, J. G., Duckett, S. K., Hunt, C. W., Pritchard, G. T., & Owens, F. N. (2001). Effects of feeding high-oil corn to beef steers on carcass characteristics and meat quality. *J. Anim. Sci., 79*, 582-588. https://doi.org/10.2527/2001.793582x

Barendse, W. (2014). Should animal fats be back on the table? A critical review of the human health effects of animal fat. *Animal Production Science, 54*, 831-855.https://doi.org/10.1071/AN13536

Barletta, R. V., Gandra, J. R., Bettero, V. P., Araújoa, C. E., Valle, T. A. D., Almeida, G. F., … Rennó, F. P. (2016). Ruminal biohydrogenation and abomasal flow of fatty acids in lactating cows: Oilseed provides ruminal protection for fatty acids. *Animal Feed Science and Technology, 219*, 111-121. https://doi.org/10.1016/j.anifeedsci.2016.06.011

Bartle, S. J., Preston, R. L., & Miller, M. F. (1994). Dietary energy source and density: Effects of roughage source, roughage equivalent, tallow level, and steer type on feedlot performance and carcass characteristics. *J. Anim. Sci., 72*, 1943-1953.

Bauman, D. E., et al. (1999). Biosynthesis of conjugated linoleic acid in ruminants. *Proceedings of the American Society of Animal Science, 77*, 11-15.

Bee, G., Biolley, C., Guex, G., Herzog, W., Lonergan, S. M., & Huff-Lonergan, E. (2006). Effects of available dietary carbohydrate and preslaughter treatment on glycolytic potential, protein degradation, and quality traits of pig muscles. *Journal of Animal Science, 84*,191-203. https://doi.org/10.2527/2006.841191x

Berg, J. M., Tymoczko, J. L., & Stryer, L. (2006). *Biochemistry* (6th ed., p. 1026). New York, NY: W.H. Freeman and Company.

Bertrand, J. A., et al. (2005). Nutrient content of whole cottonseed. *Journal of Dairy Science, 88*, 1470-1477. https://doi.org/10.3168/jds.S0022-0302(05)72815-0

Calsamiglia, S., Cardozo, P. W., Ferret, A., & Bach, A. (2008). Changes in rumen microbial fermentation are due to a combined effect of diet and pH. *J. Anim. Sci., 86*, 702-711. https://doi.org/10.2527/jas.2007-0146

Carvalho, I. P. C., Fiorentini, G., Lage, J. F., Messana, J. D., Canesin, R. C., Rossi, L. G., … Berchielli, T. T. (2016). Fatty acid profile, carcass traits and meat quality of Nellore steers following supplementation with various lipid sources. *Animal Production Science*. https://doi.org/10.1071/AN15149

Castagnino, P. S., Messanaa, J. D., Fiorentini, G., Jesus, R. B., San Vitoa, E., Carvalho, I. P. C., & Berchielli, T. T. (2015). Glycerol combined with oils did not limit biohydrogenation of unsaturated fatty acid but reduced methane production *in vitro*. *Animal Feed Science and Technology, 201*, 14-24. https://doi.org/10.1016/j.anifeedsci.2014.12.004

Chilliard, Y., et al. (2000). Ruminant milk fat plasticity: Nutritional control of saturated, polyunsaturated, trans and conjugated fatty acids. *Annales de Zootechnie, 49*, 181-205. https://doi.org/10.1051/animres:2000117

Chilliard, Y., Ferlay, A., & Doreau, M. (2001). Effect of different types of forages, animal fat or marine oils in cow's diet on milk fat secretion and composition, especially conjugated linoleic acid (CLA) and polyunsaturated fatty acids. *Livestock Production Science, 70*. https://doi.org/10.1016/S0301-6226(01)00196-8

Conjugated Linoleic Acid For Weight Loss. (March 21, 2017). Retrieved from http://dietpill-reviews.co.uk/conjugated-linoleic-acid-for-weight-loss

Costa, D. P. B., Roça, R. O., Costa, Q. P. B., Lanna, D. P. D., Lima, E. S., & Barros, W. M. (2013). Meat characteristics of Nellore steers fed whole cottonseed. *Braz. J. Anim. Sci., 42*, 183-192. https://doi.org/10.1590/S1516-35982013000300006

De La Totte, A., et al. (2006). Factors influencing proportion and composition of CLA in beef. *Meat Science, 73*, 258-268. https://doi.org/10.1016/j.meatsci.2005.11.025

Demeyer, D., & Doreau, M. (1999). Targets and procedures for altering ruminant meat and milk lipids. *Proceedings of the Nutrition Society, 58*, 593-607. https://doi.org/10.1017/S0029665199000786

Domingues, J. L., Nuñez, A. J. C., Gomes, R. C., Valinote, A. C., Silva, S. L., Pereira, A. S. C., … Nogueira Filho, J. C. M. (2015). Effect of high oil corn in the diets of Nellore steers on growth performance, carcass characteristics, meat quality, and longissimus muscle fatty acid profile. *Livestock Science, 174*, 31-38. https://doi.org/10.1016/j.livsci.2014.12.019

Donicht, P. A. M. M. (2011). *Efeitos da espessura de gordura, conformação, peso da carcaça, idade sobre a qualidade da carcaça e da carne de vacas de descarte* (Ph.D. Thesis, p. 174). UFSM-RS.

Duckett, S. K. (2017). *Effects of nutrition and management practices on marbling deposition and composition*. Retrieved from http://www.cabpartners.com/news/research/duckett_nutrition.pdf

Enemark, J. M. D. (2008). The monitoring, prevention and treatment of sub-acute ruminal acidosis (SARA): a review. *Vet J., 176*, 32-43. https://doi.org/10.1016/j.tvjl.2007.12.021

Fadel, H. H. M., Samad, A. A., Kobeasy, M. I., Mageed, M. A. A., & Shereen, N. L. (2015). Flavour quality and stability of an encapsulated meat-like process flavouring prepared from soybean based acid hydrolyzed protein. *International Journal of Food Processing Technology, 2*, 17-25. https://doi.org/10.15379/2408-9826.2015.02.01.3

Feijó, G. D., Mele, M., Barros, P. E. P., Marino, C. T., Ciucci, F., Bonin, M. N., & Verbisck, N. V. (2016). Fatty acid composition of intramuscular lipids from Nellore and Brangus bulls fed diets supplemented with cottonseed. *J. Anim. Sci., 94*(E-Suppl. 5), 619.

Fiorentini, G. (2009). *Fontes lipídicas na terminação de novilhas* (p. 57). Dissertação (Mestrado em Zootecnia/Produção Animal), Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal.

French, P., et al. (2000). Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass silage, or concentrate-based diets. *Journal of Animal Science, 78*, 2849-2855. https://doi.org/10.2527/2000.78112849x

Griinari, J. M., et al. (2000). Conjugated linoleic acid is synthesized endogenously in lactating dairy cows by delte-9 desaturase. *Journal of Nutrition, 130*, 2285-2291.

Gunstone, F. D. (2006). *Modifying Lipids for Use in Food* (p. 608). Woodhead Publishing Limited.

Harfoot, C. G., & Hazlewood, G. P. (1988). Lipid metabolism in the rumen. In P. N. Hobson (Ed.), *The rumen microbial ecosystem* (pp. 285-322). London: Elsevier Applied Science.

Harmon, D. L., Yamka, R. M., & Elam, N. A. (2004). Factors affecting intestinal starch digestion in ruminants: A review. *Can. J. Anim. Sci., 84*, 309-318. https://doi.org/10.4141/A03-077

Hui, Y. H. (2012). *Handbook of Meat and Meat Processing* (2nd ed., p. 982). CRC Press. https://doi.org/10.1201/b11479

Ibrahim, R. M., Goll, D. E., Marchello, J. A., Duff, G. C., Thomson, V. F., Mares, S. W., & Ahmad, H. A. (2008). Effect of two dietary concentrate levels on tenderness, calpain and calpastatin activities, and carcass merit in Waguli and Brahman steers. *Journal of Animal Science, 86*, 1426-1433. https://doi.org/10.2527/jas.2007-0618

Jenkins, T. C. (1993). Symposium: Advances in ruminant lipid metabolism. Lipid metabolism in the rumen. *Journal of Dairy Science, 76*, 3851-3863. https://doi.org/10.3168/jds.S0022-0302(93)77727-9

Jenkins, T. C., & Palmiquist, D. L. (1984). Effect of fatty acids or calcium soaps on rumen and total nutrient digestibility of dairy rations. *Journal of Dairy Science, 67*, 971-979. https://doi.org/10.3168/jds.S0022-0302(84)81396-X

Jenkins, T. C., Wallace, R. J., Moate, P. J., & Mosley, E. E. (2008). Board-invited review: Recent advances in biohydrogenation of unsaturated fatty acids within the rumen microbial ecosystem. *J. Anim. Sci., 86*, 397-412. https://doi.org/10.2527/jas.2007-0588

Jorge, J. R. V., et al. (2009). Gordura protegida sobre o desempenho, carcaça e composição química da carne de novilhos Holandês. *Archivos de Zootecnia, 58*, 371-382. https://doi.org/10.4321/S0004-05922009000300006

Juárez, M., Dugan, M. E. R., Aalhus, J. L., Aldai, N., Basarab, J. A., Baron, V. S., & McAllister, T. A. (2011). Effects of vitamin E and flaxseed on rumen-derived fatty acid intermediates in beef intramuscular fat. *Meat Science, 88*, 434-440. https://doi.org/10.1016/j.meatsci.2011.01.023

Juárez, M., Dugan, M. E. R., Aldai, N., Basarab, J. A., Baron, V. S., McAllister, T. A., & Aalhus, J. L. (2012). Beef quality attributes as affected by increasing the intramuscular levels of vitamin E and omega-3 fatty acids. *Meat Science, 90*, 764-769. https://doi.org/10.1016/j.meatsci.2011.11.010

King, D. A., Pfeiffer, C. E. S., Randel, R. D., Welsh, T. H., Oliphint, R. A., Baird, B. E., et al. (2006). Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. *Meat Science, 74*, 546-556. https://doi.org/10.1016/j.meatsci.2006.05.004

Klusmeyer, T. H., & Clark, J. H. (1991). Effects of dietary fat and protein on fatty acid flow to the duodenum and in milk produced by dairy cows. *Journal of Animal Science, 74*, 3055-3067. https://doi.org/10.3168/jds.s0022-0302(91)78491-9

Krause, D. O., Nagaraja, T. G., Wright, A. D., & Callaway, T. R. (2014). Board-invited review: Rumen microbiology: Leading the way in microbial ecology. *J. Anim. Sci., 91*, 331-34. https://doi.org/10.2527/jas.2012-5567

Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2000). *Lehninger principles of biochemistry* (p. 680). New York: Worth Publishers.

Lima, E. S., Morais, J. P. G., Roça, R. O., Andrade, E. N., Valente, T. N. P., Costa, Q. P. B., & Deminicis, B. B. (2015b). Effect of different sources of lipids in diet on the qualitative characteristics of Longissimus thoracis muscle of cattle finished in feedlots. *African Journal Agricultural Research, 10*, 2835-2840. https://doi.org/10.5897/AJAR2015.10064

Lima, E. S., Morais, J. P. G., Roça, R. O., Costa, Q. P. B., Andrade, E. N., Vaz, V. P., … Costa, D. P. B. (2015a). Meat Characteristics of Nellore Cattle Fed Different Levels of Lipid-Based Diets. *Journal of Agricultural Science, 7*, 174-183. https://doi.org/10.5539/jas.v7n7p174

Lima, E. S., Morais, J. P. G., Roça, R. O., Valente, T. N. P., Andrade, E. N., & Deminicis, B. B. (2016). Performance and carcass characteristics of cattle fed lipid sources in the diet. *Can. J. Anim. Sci., 96*, 581-588. https://doi.org/10.1139/cjas-2015-0203

Lourenço, M., Ramos-Morales, E., & Wallace, R. J. (2010). The role of microbes in rumen lipolysis and biohydrogenation and their manipulation. *Animal, 4*, 1008-1023. https://doi.org/10.1017/S1751731 11000042X

Mach, N., Bach, A. Velarde, A., & Devant, M. (2006). Association between animal, transportation, slaughterhouse practices, and meat pH in beef. *Meat Science, 78*, 232-238. https://doi.org/10.1016/ j.meatsci.2007.06.021

Malik, P. K., Bhatta, R, Takahashi, J., Kohn, R., & Prasad, C. S. (2015). *Livestock Production and Climate Change* (p. 407). CABI. https://doi.org/10.1079/9781780644325.0000

Mancini, R. A., & Ramanathan, R. (2014). Effects of postmortem storage time on color and mitochondria in beef. *Meat Sci., 98*, 65-70. https://doi.org/10.1016/j.meatsci.2014.04.007

Mangrum, K. S., Tuttle, G., Duckett, S. K., Sell, G. S., Krehbiel, C. R., & Long, N. M. (2016). The effect of supplementing rumen undegradable unsaturated fatty acids on marbling in early-weaned steers1. *J. Anim. Sci., 94*, 833-844. https://doi.org/10.2527/jas.2015-9809

Mattos, R., Staples, C. R., & Thatcher, W. W. (2000). Effects of dietary fatty acids on reproduction in ruminants. *Reviews of Reproduction, 5*(1), 38-45. https://doi.org/10.1530/ror.0.0050038

McGuire, M. A., & McGuire, M. K. (2010). Conjugated linoleic acid (CLA): a ruminant fatty acid with beneficial effects on human health. *Proceedings of the American Society of Animal Science*. Retrieved from http://www.journalofanimalscience.org/content/77/E-Suppl/1.33

Messana, J. D., Berchielli, T. T., Arcuri, P. B., Reis, R. A., Canesin, R. C., Ribeiro, A. F., … Fernandes, J. J. R. (2013). Rumen fermentation and rumen microbes in Nellore steers receiving diets with different lipid contents. *Braz. J. Anim. Sci., 42*, 204-212. https://doi.org/10.1590/s1516-35982013000300008

Mir, P. S., McAllister, T. A., Zaman, S., Morgan Jones, S. D., He, M. L., Aalhus, J. L., … Mir, Z. (2003). Effect of dietary sunflower oil and vitamin E on beef cattle performance, carcass characteristics and meat quality. *Can. J. Anim. Sci., 83*, 53-66. https://doi.org/10.4141/A02-014

Mosley, E. E., et al. (2006). cis-9, trans-11 conjugated linoleic acid is synthesized directly from vaccenic acid in lactating dairy cattle. *Journal of Nutrition, 136*, 570-575.

Mottram, D. S. (1998). Flavour formation in meat and meat products: a review. *Food Chemistry, 62*, 415-424. https://doi.org/10.1016/S0308-8146(98)00076-4

Muller, M., et al. (2005). Diferentes fontes de gordura sobre o desempenho e características da carcaça de novilhas de corte confinadas. *Acta Scientiarum, 27*, 131-137. https://doi.org/10.4025/actascianimsci. v27i1.1250

Nelson, D. L., Cox, M., & Lehninger, M. (2008). *Principles of biochemistry* (6th ed., p. 1158). New York, W. H. Freeman and Company.

Nuernberga, K., Dannenbergera, D., Nuernberga, G., Endera, K., Voigta, J., Scollanb, N. D., … Richardsonc, R. I. (2005). Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of longissimus muscle in different cattle breeds. *Livestock Production Science, 94*, 37-147. https://doi.org/10.1016/j.livprodsci.2004.11.036

Oliveira, D. M., Ladeira, M. M., Chizzotti, M. L., et al. (2011). Fatty acid profile and qualitative characteristics of meat from Zebu steers fed with different oilseeds. *Journal of Animal Science, 89*, 2546-2555. https://doi.org/10.2527/jas.2010-3553

Or-Rashid, M. M., AlZahal, O., & McBride, B. W. (2011). Comparative studies on the metabolism of linoleic acid by rumen bacteria, protozoa, and their mixture in vitro. *Applied Microbiology and Biotechnology, 89*, 387-395. https://doi.org/10.1007/s00253-010-2865-z

Palmiquist, D. L. (1994). The role of dietary fats in efficiency of ruminants. Conference: regulating lipids metabolism to increase productive efficiency. *Journal of Nutrition, 124*, 1377-1382.

Patil, A. R., Goetsch, A. L., Lewis Jr, P. K., & Heird, C. E. (1993). Effects of suplementing growing steers with high levels of partially hydrogenated tallow on feed intake, digestibility, live weight gain, and carcass characteristics. *Journal of Animal Science, 71*, 2284-2292.

Pesce, D. M. C. (2008). *Effect of diet containing cottonseed on performance, quantitative and qualitative carcass characteristics of meat of Nellore steers confined* (PhD thesis, School of Animal Science and Food Engineering, University of Sao Paulo, Brazil).

Pires, I. S. C., et al. (2008). Composição centesimal e perfil de ácidos graxos da carne de novilho precoce alimentado com lipídios protegidos. *Ciência e Tecnologia de Alimentos, 28*, 178-183. https://doi.org/10.1590/S0101-20612008000500028

Putrino, S. M. (2006). *Composição corporal, exigências de energia e proteína para ganho e composição da carne de novilhos Nelore alimentados com dietas com milho grão seco ou úmido contendo gordura não degradável no rúmen* (Ph.D Thesis, p. 100, USP-SP, in Portuguese).

Russell, J. B. (2002). *Rumen Microbiology and its role in ruminant nutrition* (p. 119). Ithaca, NY.

Russell, J. B., & Strobel, H. J. (2005). Microbial energetics. In J. Dijkstra, J. M. Forbes, & J. France (Eds.), *Quantitative aspects of ruminant digestion and metabolism* (2nd ed., pp. 229-261). https://doi.org/10.1079/9780851998145.0229

Sander, A. B. T. (2000). Polyunsaturated fatty acids in the food chain in Europe. *The American Journal of Clinical Nutrition, 71*, 176-178.

Schimid, A., et al. (2006). Conjugated linoleic acid in meat and meat products: A review. *Meat Science, 73*, 29-41. https://doi.org/10.1016/j.meatsci.2005.10.010

Schneider, C. L., et al. (2000). Dietary Stearic Acid Reduces Cholesterol Absorption and Increases Endogenous Cholesterol Excretion in Hamsters Fed Cereal-Based Diets. *The Journal of Nutrition, 130*, 232-238.

Shackelford, S. D., Koohmarie, M., Cundiff, L. V., Gregory, K. E., Rohrer, G. A., & Savell, J. W. (1994). Heritabilities and phenotypic and genetic correlations for bovine post rigor calpastatin activity, intramuscular fat content, Warner Bratzler shear force, retail product yield, and growth rate. *J. Anim. Sci., 72*, 857-863.

Shibuya, C. M. (2004). *Sensory analysis of meat (m. L. thoracis) of steers finished on dry vs. humid corn with or without protected fat (lactoplus), and lactoplus vs. cottonseed* (Thesis, Master's degree in Food Technology, p. 87). Universidade Estadual de Campinas, Faculdade de Engenharia de Alimentos, Campinas.

Shingfield, K. J., et al. (2005). Effect of forage type and proportion of concentrate in the diet on milk fatty acid composition in cows given sunflower oil and fish oil. *Animal Science, 80*, 225-238. https://doi.org/10.1079/ASC41820225

Silva, S. L., Leme, P. R., Putrino, S. M., Pereira, A. S. C., Valinote, A. C., Nogueira Filho, J. C. M., & Lanna, D. P. D. (2009). Fatty acid composition of intramuscular fat from Nellore steers fed dry or high moisture corn and calcium salts of fatty acids. *Livestock Science, 122*, 290-295. https://doi.org/10.1016/j.livsci.2008.09.013

Smith, S. B., Gill, C. A., Lunt, D. K., & Brooks, M. A. (2009). Regulation of Fat and Fatty Acid Composition in Beef Cattle. *Asian-Aust. J. Anim. Sci., 22*, 1225-1233. https://doi.org/10.5713/ajas.2009.r.10

Souza, N. E., et al. (2007). Grãos de linhaça e canola sobre a composição do músculo Longissimus de novilhas confinadas. *Archivos de Zootecnia, 56*, 863-874.

Stipanuk, M. H. (2000). *Biochemical and physiological aspects of human nutrition* (1st ed., p. 1007). New York: W. B. Saunders.

Suen, G., Stevenson, D. M., Bruce, D. C., Chertkov, O., Copeland, A., Cheng, J. F., … Hauser, L. J. (2011). Complete genome of the cellulolytic ruminal bacterium Ruminococcus albus. *J. Bacteriol., 193*, 5574-5575. https://doi.org/10.1128/JB.05621-11

Suman, S. P., Hunt, M. C., Nair, M. N., & Rentfrow, G. (2014). Improving beef color stability: Practical strategies and underlying mechanisms. *Meat Sci., 98*, 490-504. https://doi.org/10.1016/j.meatsci.2014.06.032

Tatum, J. D., Smith, G. C., & Belk, K. E. (2000). New approaches for improving tenderness, quality, and consistency of beef. *Proceedings of American Society of Animal Science, 2000, California* (pp. 1-10). California: American Society of Animal Science.

Teixeira, N. F. (2003). *Nutrição clínica* (1st ed., p. 519). Rio de Janeiro: Guanabara Koogan.

Toldr, F. (2010). *Handbook of meet processing* (p. 561). Blackwell Publishing. https://doi.org/10.1002/9780813820897.index

Valente, T. N. P., Detmann, E., & Sampaio, C. B. (2015). Review: Recent advances in evaluation of bags made from different textiles used in situ ruminal degradation. *Can. J. Anim. Sci., 95*, 493-498. https://doi.org/10.4141/cjas-2015-100

Valente, T. N. P., Lima, E. S., Santos, W. B. R., Cezário, A. S., Tavares, C. J., Fernandes, I. L., & Freitas, M. A. M. (2016). Ruminal microorganism consideration and protein used in the metabolism of the ruminants: A Review. *Afr. J. Microbiol. Res., 10*, 456-464. https://doi.org/10.5897/AJMR2016.7627

Valente, T. N. P., Sampaio, C. B., Lima, E. S., Deminicis, B. B., Cezário, A. S., & Santos, W. B. R. (2017). Aspects of acidosis in ruminants with a focus on nutrition: A review. *J Agric Sci., 9*(3), 90-97. https://doi.org/10.5539/jas.v9n3p90

Valinote, A. C., et al. (2005). Fontes de lipídios e monensina na alimentação de novilhos Nelore e sua relação com a população de protozoários ciliados do rúmen. *Brazilian Journal of Animal Science, 34*, 1418-1423.

Valinote, A. C., et al. (2006). Fontes de lipídio e monensina sódica na fermentação, cinética e degradabilidade ruminal de bovinos. *Pesquisa Agropecuária Brasileira, 41*,117-124. https://doi.org/10.1590/S0100-204X2006000100016

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant* (2nd ed., p. 476).

Vargas, L. H., et al. (2002). Adição de lipídios na ração de vacas leiteiras: Parâmetros ruminais, produção e composição do leite. *Brazilian Journal of Animal Science, 31*, 522-529. https://doi.org/10.1590/s1516-35982002000200029

Veracini, J. L., Walker, P. M., Faulkner, M. J., Hall, R. E., Atkinson, R. L., & Wiegand, B. R. (2013). Effects of high fat, modified wet, corn distiller's grains plus solubles on beef steer performance and carcass characteristics. *Livestock Science, 157*, 151-161. https://doi.org/10.1016/j.livsci.2013.07.014

Warren, H. E., Scollan, N. D., Enser, M., Hughes, S. I., Richardson, R. I., & Wood, J. D. (2008). Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. I: Animal performance, carcass quality and muscle fatty acid composition. *Meat Science, 78*(3), 256-269. https://doi.org/10.1016/j.meatsci.2007.06.008

Watanabe, A., Kamada, G., Imanari, M., Shiba, N., Yonai, M., & Muramoto, T. (2015). Effect of aging on volatile compounds in cooked beef. *Meat Sci., 107*, 12-19. https://doi.org/10.1016/j.meatsci.2015.04.004

Wills, W. M., Lencki, R. E., & Marangoni, A. G. (1988). Lipid modification strategies in the production of nutritionally functional fats and oils. *Criticals Reviews in Food Science and Nutrition, 38*, 639-674. https://doi.org/10.1080/10408699891274336

Abbreviations

DM, dry matter; DMI, dry matter intake; CLAs, conjugated linoleic acid; CS, cottonseed; EFAs, essential fatty acid; FA, fatty acid; MUFA, monounsaturated fatty acids; NDF, neutral detergent fiber; PUFA, polyunsaturated fatty acids; SCFA, calcium salts of fatty acids; SFA, saturated fatty acids; UFAs, unsaturated fatty acids; VFA, volatile fatty acid.

Copyrights