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ENERGY SOURCES IN THE SUPPLEMENTATION OF BEEF CATTLE GRAZING *BRACHIARIA BRIZANTHA CV*. XARAÉS

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2016

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Orientadora: Profa. Dra. Telma Teresinha Berchielli

Tese apresentada à Faculdade de Ciências Agrárias e Veterinárias - UNESP, Câmpus de Jaboticabal, como parte das exigências para a obtenção do Título de Doutor em Zootecnia

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TÍTULO DA TESE: ENERGY SOURCES IN THE SUPPLEMENTATION OF BEEF CATTLE GRAZING *BRACHIARIA BRIZANTHA CV.* XARAÉS.

AUTOR: ANTONIO JOSÉ NETO
ORIENTADORA: TELMA TERESINHA BERCHIELLI

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Jaboticabal, 18 de fevereiro de 2016

DADOS CURRICULARES DO AUTOR

ANTONIO JOSE NETO – nascido em 10 de março de 1985, na cidade de Campos Belos, Goiás (GO), filho de Almir Eustáquio de Queiroz e Maria das Graças Cardoso Queiroz, ingressou no curso de Zootecnia em Lavras (MG), na Universidade Federal de Lavras (UFLA) em agosto de 2005, graduando-se em fevereiro de 2010. De janeiro a março de 2009 realizou estágio supervisionado no Departamento de Ciência Animal da Escola Superior Agrária do Instituto Politécnico de Bragança - Bragança, Portugal, onde desenvolveu actividades no Laboratório de Qualidade da Carne e da Carcaça, com foco na utilização da ultrassonografia para estimar a composição corporal dos animais, sob orientação do Prof. Dr. Alfredo Jorge Costa Teixeira. Em março de 2010, ingressou no Curso de Pós-Graduação em Ciência Animal, em nível de Mestrado, na Universidade Federal de Mato Grosso (UFMT), campus de Cuiabá (MT), sob orientação do Prof. Dr. Joanis Tilemahos Zervoudakis, obtendo o título de mestre em fevereiro de 2012. Em março de 2012, ingressou no Curso de Pós-Graduação em Zootecnia, em nível de Doutorado, na Faculdade de Ciências Agrárias e Veterinárias da Universidade Estadual Paulista "Júlio de Mesquita Filho", campus de Jaboticabal (SP), sob orientação da Profa. Dra. Telma Teresinha Berchielli. De setembro de 2014 a julho de 2015 realizou Doutorado - Sanduíche no Agricultural Research and Development Center of Department of Animal Science of University of Nebraska - Lincoln, Nebraska, Estados Unidos, onde acompanhou estudos na área de utilização de subprodutos na dieta de ruminantes sob orientação do Prof. Dr. Galen E. Erickson.

"As conquistas vem quando você cancela as desculpas e transforma as adversidades em determinação."

(autor desconhecido)

"If you have a dream, don't just sit there. Gather courage to believe that you can succeed and leave no stone unturned to make it a reality."

Dr. Roopleen

Dedico

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SUMMARY

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CERTIFICADO

Certificamos que o Protocolo nº 021119/11 do trabalho de pesquisa intitulado **"Balanço de gases de efeito estufa e estratégias de mitigação em pastos de Brachiaria submetidos a diferentes manejos"**, sob a responsabilidade da Profª. Drª. Telma Teresinha Berchielli está de acordo com os Princípios Éticos na Experimentação Animal, adotado pelo Colégio Brasileiro de Experimentação (COBEA) e foi aprovado pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA), em reunião ordinária de 07 de Outubro de 2011.

Jaboticabal, 11 de Outubro de 2011.

Prof. Dr. Jeffrey Frederico Lui
Presidente - CEUA

Med. Vet. Maria Alice de Campos
Secretária - CEUA

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ENERGY SOURCES IN THE SUPPLEMENTATION OF BEEF CATTLE GRAZING *BRACHIARIA BRIZANTHA CV.* XARAÉS

ABSTRACT – In the first experiment, one hundred and four (initial BW = 284 ± 38 kg) and sixty (initial BW = 424 ± 34 kg) Nellore bulls were used to evaluate the performance and final carcass characteristics of Nellore bulls during two phases: growing and finishing phase, respectively. The diets used consisted in *Brachiaria brizantha cv.* Xaraés pasture supplemented with two levels of starch, with or without a source of oil. The supplements were corn associated or not with ground soybean (GS) and soybean hulls (SH) associated or not with ground soybean. In relation to animal performance during growing phase, there were no interaction (*P* = 0.14) between starch level and oil for final BW, ADG, and CrG. However, the addition of oil decreased final BW (*P* = 0.01), ADG (*P* < 0.01), total gain (*P* < 0.01) and CrG (*P* = 0.01). On the other hand, during finishing phase, there were no interaction (*P* = 0.11) between starch level and oil for, final BW, ADG, HCW, dressing, CrG, fat depth, and LM area. In contrast, animals supplemented with oil increased final BW (*P* = 0.01), ADG (*P* = 0.02), total gain (*P* = 0.01), HCW (*P* < 0.01), CrG (*P* = 0.01), and fat depth (*P* = 0.04). Furthermore, there was effect of time during growing and finishing phase on values of ADG (*P* < 0.01) of Nellore bulls. Soybean hulls have a similar energy value to corn when used in supplements to beef cattle on tropical pasture during growing and finish phase. The use of oil supplementation may be effective to reduce enteric CH_4 emissions of Nellore bulls fed *Brachiaria brizantha cv*. Xaraés during the growing and finishing phase, and in addition, may improve performance and final carcass traits of Nellore bulls, only during the finish phase. In another experiment, aimed to evaluate the combined effects of high- or low-starch supplements and oil on intake, digestibility, performance, and methane (CH_4) emissions of growing (n = 44, initial BW = 250.69 ± 27 kg) and finishing (n = 44, initial BW = 414 ± 12 kg) Nellore bulls fed tropical pasture of *Brachiaria brizantha cv.* Xaraés during the rainy and dry season, respectively. Eight animals were slaughtered at a commercial beef plant and served as the reference group at the beginning of each experiment. The other thirty-six animals were distributed in a completely randomized design (three animals per paddock and three paddocks per treatment). The experimental period lasted 133 d, divided into an adaptation period of 21 d and four periods of 28 d each. The supplements were: corn combined with GS; corn without GS; SH combined with GS; and SH without GS. Crude glycerin was used in all supplements to replace (28% of DM) corn or SH. In relation to growing phase, there were no interactions between starch level and oil supplementation on intake of DM (*P* = 0.67), NDF (*P* = 0.50), and EE (*P* = 0.47); on digestibility of DM (*P* = 0.18) and NDF (*P* = 0.42); on final BW (*P* = 0.94), ADG (*P* = 0.40), FE (*P* = 0.37); and on CH_4 emissions when expressed in g/d (*P* = 0.77), kg/yr (*P* = 0.77), g/kg DMI (*P* = 0.53). However, independently of starch level utilized, the animals supplemented with oil increased intake of EE (*P* < 0.01); decreased the digestibility of OM (*P* = 0.04) and NDF (*P* = 0.03); and decreased enteric CH_4 emission when corrected for intake of GE (*P* = 0.04) and EE (*P* < 0.01). In finishing phase, there were no interactions between starch level and oil supplementation on intake of DM (*P* = 0.90), NDF (*P* = 0.65), and EE (*P* = 0.56); on digestibility of DM (*P* = 0.12) and

NDF (*P* = 0.12); on final BW (*P* = 0.37), ADG (*P* = 0.41), FE (*P* = 0.47), HCW (*P* = 0.83), dressing (*P* = 0.41), carcass gain (*P* = 0.98), fat depth (*P* = 0.36) and LM area (*P* = 0.91); and on CH_4 emissions when expressed in g/d (*P* = 0.78), kg/yr (*P* = 0.78), g/kg DMI (*P* = 0.81), g/kg ADG (*P* = 0.48), and g/kg of carcass gain (*P* = 0.85). However, independently of starch level utilized, the animals supplemented with oil decreased the digestibility of NDF (*P* = 0.03) and increased EE digestibility (*P* < 0.01); increased the fat depth (*P* = 0.01); and decreased enteric CH_4 emission expressed in g/d (*P* = 0.04) and kg/yr (*P* = 0.04), and when was corrected to GE (*P* = 0.02) and EE (*P* < 0.01) intake, and ADG (*P* = 0.02) for animals fed high- or low-starch supplement. In growing or finishing phase, soybean hulls have the similar estimated feeding value to that of corn, and the use of oil supplementation may be effective to reduce enteric methane emission of Nellore bulls grazing tropical pasture. Regarding the study of cannulated animals, the objective was evaluate the effect of oil supplementation combined with high- or low-starch on intake, nutrient digestibility, rumen fermentation parameters, and rumen microbial profile of young Nellore steers grazing *Brachiaria brizantha cv.* Xaraés during two phases: growing and finishing. In the growing phase, eight ruminal cannulated Nellore steers (424.8 kg ± 35.5) at 20 mo of age were used in a replicate 4 × 4 Latin square with a 2 × 2 factorial arrangement of treatments (high or low starch, with or without a source of oil) and an experimental period of 21 d. The supplements were corn combined with GS; corn without GS; SH combined with GS; and SH without GS. Animals were supplemented at the rate of 500 g/100kg BW. There were no interactions between starch level and oil supplementation on DM and nutrients intake (*P* > 0.01). The addition of oil decreased the intake of DM (*P* = 0.01), forage DM (*P* < 0.01), OM (*P* = 0.01), CP (*P* = 0.02), NDF (*P* < 0.01), and GE (*P* = 0.01), independently of starch level used. Animals fed with low-starch and without oil had greater digestibility of DM (*P* < 0.01), OM (*P* < 0.01), CP (*P* < 0.01), NDF (*P* = 0.01), and GE (*P* = 0.01) than animals fed with other supplements. The addition of oil in the supplements decreased the pH (*P* = 0.02) and NH_3-N (*P* = 0.02); and decreased the numbers of Dasytricha (*P* < 0.01), Isotricha (*P* < 0.01), and total protozoa (*P* < 0.01). The percentage of *Ruminococcus albus* (*P* = 0.0003), *Ruminococcus flavefaciens* (*P* = 0.0002), and *Archeas* (*P* < 0.0004) were higher for low-starch without oil diets than for other diets. Additionally, animals supplemented with oil decreased the number of *Fibrobacter succinogenes* (*P* = 0.0003), independently of starch level used. Oil supplementation reduce intake, protozoa population, and fibrolytic rumen bacteria. The use of low-starch supplementation without oil may be effective to increase digestibility of DM and nutrient, and *Ruminococcus albus*, *Ruminococcus flavefaciens*, and *Archeas* population in the rumen of growing Nellore steers grazing tropical pasture. In the finishing phase, eight ruminal cannulated Nellore steers (514.5 kg ± 30.1) at 24 mo of age were used in a replicate 4 × 4 Latin square with a 2 × 2 factorial arrangement of treatments (high or low starch, with or without a source of oil) and an experimental period of 21 d. The supplements were corn combined with GS; corn without GS; SH combined with GS; and SH without GS. Animals were supplemented at the rate of 1000 g/100 kg BW. There were no interactions between starch-based supplementation level and oil with regard to DM and nutrients intake (*P* > 0.05). Animals supplemented with low starch and no oil showed greater (10.77%) digestibility of CP (*P* = 0.01) than those supplemented with high-starch and no oil. Total apparent digestibility of DM (P < 0.01), OM (*P* < 0.01), NDF (*P* = 0.03), and GE

(P = 0.02) decreased with oil supplementation. There were no interactions between starch × oil for pH, NH_3-N, and total VFA (P > 0.05). Animals supplemented with oil showed lower acetate production (P < 0.01) than those supplemented without oil, independent of starch level. The addition of oil in the supplements decreased the population of Dasytricha (P < 0.01), Polyplastron (P < 0.21), and Diploplastron (P = 0.04). Supplementing the animals with low-starch without oil increased the numbers of *Ruminococcus albus* compared with the other supplements (P = 0.0120). There was also interaction between starch × oil for *Selenomonas ruminantium* (P = 0.0003), once low-starch supplement, with or without oil, decreased the number of *Selenomonas ruminantium* of Nellore steers. The addition of oil in the supplements decreased the number of *Fibrobacter succinogenes* (P < 0.0001), *Ruminococcus flavefasciens* (P < 0.0001), and *Archeas* (P < 0.0001), but increased of *Anaerovibrio lipolytica* (P < 0.0001), independently of starch level used. Oil supplementation decreases the intake, digestibility, acetate production, protozoa population, and fibrolytic rumen bacteria. The use of soybean hulls without oil supplementation may be effective to increase digestibility of CP, and *Ruminococcus albus* of finishing Nellore steers grazing *Brachiaria brizantha cv.* Xaraés during the dry season. The last study evaluated the fatty acid intake, fatty acid composition, and meat quality traits of 60 young Nellore bulls fed diets with two levels of starch-based supplement with or without a source of oil (ground soybean; GS). The supplements were corn without GS, corn associated with GS, soybean hulls (SH) without GS, and SH associated with GS. There were interaction between starch-based supplementation level and oil to intake of vaccenic (P < 0.01), linoleic (P < 0.01), Total PUFA (P = 0.01). Meat from animals supplemented with-high starch and without oil increased the percentage of vaccenic acid (P = 0.01). The use of low-starch supplements with oil increases intake of linoleic and total PUFA. Starch-based or oil supplementation not affect the myristic or palmitic acid content in the *longissimus dorsi* muscle. Oil supplementation increases the level of stearic acid and the n-6/n-3 ratio, but decreases the percentage of linolenic acid in muscle of Nellore bulls grazing *Brachiaria brizantha* cv. Xaraés during finishing phase.

Keywords: fatty acid, glycerol, methane, Nellore, oil, performance

FONTES DE ENERGIA NA SUPLEMENTAÇÃO DE BOVINOS DE CORTE EM PASTAGENS DE *BRACHIARIA BRIZANTHA* CV. XARAÉS

RESUMO – No primeiro experimento, foram utilizados cento e quatro (PC inicial = 284 ± 38 kg) e sessenta (PC inicial = 424 ± 34 kg) tourinhos da raça Nelore com o objetivo de avaliar os efeitos de suplementos com alto ou baixo amido, associados ou não com uma fonte de óleo, sobre o desempenho e características finais da carcaça durante duas fases: recria e terminação, respectivamente. Os suplementos utilizados foram milho sem soja grão moída (SG), milho associado com SG, casca de soja (CS) sem SG, e CS associada com SG. The experimental design was completely randomized in a 2 × 2 factorial arrangement (high or low starch, with or without a source of oil). Each paddock was considered the individual experimental unit. Em relação ao desempenho dos animais durante a fase de recria, não houve interação (P = 0,14) entre o nível de amido e óleo para o PC final, GMD e ganho de carcaça. No entanto, a adição de óleo diminuiu o PC final (P = 0,01), GMD (P < 0,01), o ganho total (P < 0,01) e ganho de carcaça (P = 0,01). Por outro lado, durante a fase de terminação, não houve interação (P = 0,11) entre o nível de amido e óleo para PC final, GMD, PCQ, rendimento de carcaça, ganho de carcaça, espessura de gordura subcutânea e AOL. No entanto, os animais suplementados com óleo aumentaram o PC final (P = 0,01), GMD (P = 0,02), ganho total (P = 0,01), PCQ (P < 0,01), o ganho de carcaça (P = 0,01) e a espessura de gordura (P = 0,04). Além disso, houve efeito do tempo durante a fase de recria e terminação para os valores de GMD (P < 0,01) dos tourinhos da raça Nelore. A casca de soja tem um valor energético semelhante ao milho quando usado em suplementos para bovinos de corte em pastagem tropical durante a fase de recria e terminação. O uso de suplementação com óleo pode ser eficaz para melhorar o desempenho e as características finais da carcaça de tourinhos da raça Nelore em pastagens de *Brachiaria brizantha cv.* Xaraés, somente durante a fase de terminação. No outro experimento, objetivou-se avaliar os efeitos de suplementos com alto ou baixo amido, associados ou não com óleo, sobre o consumo, a digestibilidade, desempenho e emissões de metano (CH_4) da fase de recria (n = 44, PC inicial = 250,69 ± 27 kg) e terminação (n = 44, PC inicial = 414 ± 12 kg) de tourinhos da raça Nelore alimentados com pasto tropical de *Brachiaria brizantha cv.* Xaraés durante a estação das águas e da seca, respectivamente. Oito animais foram abatidos em uma planta de frigorífico comercial de bovinos e serviu como grupo de referência no início de cada experimento. Os outros trinta e seis animais foram distribuídos em um delineamento experimental inteiramente casualizado (três animais por piquete e três piquetes por tratamento). O período experimental foi de 133 dias, divididos em um período de adaptação de 21 dias e quatro períodos de 28 dias cada. Os suplementos foram milho sem soja grão moída (SG), milho associado com SG, casca de soja (CS) sem SG, e CS associada com SG. Glicerina bruta foi utilizada em todos os suplementos para substituir (28% da MS) do milho ou da CS. Em relação à fase de recria, não houve interações entre nível de amido e suplementação com óleo sobre o consumo de MS (P = 0,67), FDN (P = 0,50) e EE (P = 0,47); sobre a digestibilidade da MS (P = 0,18) e do FDN (P = 0,42); sobre o PC final (P = 0,94), GMD (P = 0,40), e na EA (P = 0,37); e sobre as emissões de CH_4 quando expressa

em g/dia (*P* = 0,77), kg/ano (*P* = 0,77), g/kg CMS (*P* = 0,53). No entanto, independentemente do nível de amido utilizado, os animais suplementados com óleo aumentaram o consumo de EE (*P* < 0,01); diminuíram a digestibilidade MO (*P* = 0,04) e FDN (*P* = 0,03); e também, reduziram a emissão CH_4 entérica quando corrigido para consumo de EB (*P* = 0,04) e EE (*P* < 0,01). Na fase de terminação, não houve interações entre nível de amido e suplementação com óleo sobre o consumo de MS (*P* = 0,90), FDN (*P* = 0,65) e EE (*P* = 0,56); sobre a digestibilidade da MS (*P* = 0,12) e FDN (*P* = 0,12); no PC final (*P* = 0,37), GMD (*P* = 0,41), EA (*P* = 0,47), PCQ (*P* = 0,83), rendimento de carcaça (*P* = 0,41), ganho de carcaça (*P* = 0,98), espessura de gordura (*P* = 0,36) e na AOL (*P* = 0,91); e sobre a emissão de CH_4 quando expressa em g/dia (*P* = 0,78), kg/ano (*P* = 0,78), g/kg de CMS (*P* = 0,81), g/kg GMD (*P* = 0,48), e em g/kg de ganho de carcaça (*P* = 0,85). No entanto, independentemente do nível de amido utilizado, os animais suplementados com óleo diminuíram a digestibilidade da FDN (*P* = 0,03) e aumentaram a digestibilidade do EE (*P* < 0,01); aumentaram a espessura de gordura subcutânea (*P* = 0,01); e reduziram a emissão de CH_4 entérico, expresso em g/dia (*P* = 0,04) e kg/ano (*P* = 0,04), e quando foi corrigido para consumo de EB (*P* = 0,02) e de EE (*P* < 0,01), e GMD (*P* = 0,02) para os animais suplementados com alto ou baixo amido. Em relação aos estudos de parâmetros ruminais, o objetivo foi avaliar o efeito da suplementação com óleo combinado com alto ou baixo amido sobre o consumo, a digestibilidade dos nutrientes, parâmetros de fermentação ruminal e o perfil dos microrganismos no rúmen, de novilhos da raça Nelore em pastagem de *Brachiaria brizantha* cv. Xaraés durante duas fases: recria e terminação. Na fase de recria, oito animais da raça Nelore, canulados no rúmen (424,8 kg ± 35,5) e com 20 meses de idade foram usados em um quadrado latino duplo 4 × 4, com um arranjo fatorial 2 × 2 dos tratamentos (alto ou baixo amido, com ou sem fonte de óleo) e um período experimental de 21 dias. Os suplementos foram milho sem soja grão moída (SG), milho associado com SG, casca de soja (CS) sem SG, e CS associada com SG. Os animais foram suplementados à taxa de 500 g/100 kg do peso corporal. Não houve interações entre nível de amido e suplementação com óleo sobre o consumo de MS e nutrientes (*P* > 0,01). A adição de óleo diminuiu o consumo de MS (*P* = 0,01), forragem (*P* < 0,01), MO (*P* = 0,01), PB (*P* = 0,02), FDN (*P* < 0,01) e EB (*P* = 0,01), independentemente do nível de amido utilizado. Animais alimentados com baixo amido e sem óleo apresentaram maior digestibilidade da MS (*P* < 0,01), MO (*P* < 0,01), PB (*P* < 0,01), FDN (*P* = 0,01) e EB (*P* = 0,01) do que os animais alimentados com outros suplementos. A adição de óleo nos suplementos diminuiu o pH (*P* = 0,02), NH_3-N (*P* = 0,02), número de Dasytricha (*P* < 0,01), Isotricha (*P* < 0,01) e total de protozoários (*P* < 0,01). A percentagem de *Ruminococcus albus* (*P* = 0,0003), *flavefaciens Ruminococcus* (*P* = 0,0002), e *Archeas* (*P* < 0,0004) foram maiores para as dietas com baixo amido e sem óleo, do que para outras dietas. Além disso, os animais suplementados com óleo diminuiram o número de *Fibrobacter succinogenes* (*P* = 0,0003). Suplementação com óleo reduz o consumo, a população de protozoários e as bactérias fibrolíticas no rúmen. O uso de suplementos com baixo amido e sem óleo pode ser eficaz para aumentar a digestibilidade da MS e dos nutrientes, e também aumentar a população de *Ruminococcus albus*, *Ruminococcus flavefaciens*, e *Archeas* no rúmen de novilhos Nelore em pastejo, durante a fase de recria. Na fase de terminação, oito animais da raça Nelore, canulados no rúmen (514,5 kg ± 30,1) e com 24 meses de idade foram

usados em um quadrado latino duplo 4 × 4, com um arranjo fatorial 2 × 2 dos tratamentos (alto ou baixo amido, com ou sem fonte de óleo) e um período experimental de 21 dias. Os suplementos foram milho sem soja grão moída (SG), milho associado com SG, casca de soja (CS) sem SG, e CS associada com SG. Os animais foram suplementados à taxa de 1000 g/100 kg de peso corporal. Não houve interações entre o nível de amido e óleo na suplementação em relação ao consumo de MS e nutrientes ($P > 0,05$). Animais suplementados com baixo amido e sem óleo apresentaram maior (10,77%) digestibilidade da PB ($P = 0,01$) do que aqueles suplementados com alto amido e sem óleo. A digestibilidade aparente total da MS ($P < 0,01$), MO ($P < 0,01$), FDN ($P = 0,03$) e EB ($P = 0,02$) diminuiu com uso do óelo na suplementação. Não houve interações entre amido × óleo para pH, $N\text{-}NH_3$ e total de AGV ($P > 0,05$). Animais suplementados com óleo apresentaram uma menor produção de acetato ($P < 0,01$) do que aqueles suplementados sem óleo, independente do nível de amido. A adição de óleo nos suplementos diminuiu a população de Dasytricha ($P < 0,01$), Polyplastron ($P < 0,21$), e de Diploplastron ($P = 0,04$). Suplementando os animais com baixo amido e sem óleo, aumentou o número de *Ruminococcus albus* em comparação com os outros suplementos ($P = 0,0120$). Houve também uma interação entre amido × óleo para *Selenomonas ruminantium* ($P = 0,0003$), uma vez que, os suplementos com baixo amido, com ou sem óleo, diminuiram o número de *Selenomonas ruminantium* dos novilhos Nelore. A adição de óleo nos suplementos diminuiu o número de *Fibrobacter succinogenes* ($P < 0,0001$), *Ruminococcus flavefasciens* ($P < 0.0001$), e de *Archeas* ($P < 0.0001$), mas aumentou o de *Anaerovibrio lipolytica* ($P < 0.0001$). Suplementação com óleo reduziu o consumo, a digestibilidade, a produção de acetato, a população de protozoários e bactérias ruminais fibrolíticas. O uso da suplementação com casca de soja e sem óleo pode ser eficaz para aumentar a digestibilidade da PB, e a população de *Ruminococcus albus* de novilhos Nelore em pastagens de *Brachiaria brizantha* cv. Xaraés durante a fase de terminação. O último estudo avaliou a ingestão de ácidos graxos, composição de ácidos graxos e características de qualidade da carne de 60 tourinhos da raça Nelore alimentados com dietas com dois níveis de amido, com ou sem uma fonte de óleo (grão de soja moída; SG). Os suplementos foram milho sem soja grão (SG), milho associado com SG, casca de soja (CS) sem SG, e CS associada com SG. Houve interação entre o nível de amido e óleo sobre consumo de ácido vacénico ($P < 0,01$), linoleico ($P < 0,01$) e total PUFA ($P = 0,01$). A carne dos animais suplementados com alto amido e sem óleo aumentou a porcentagem de ácido vacênico ($P = 0,01$). O uso de suplementos com baixo amido e com óleo aumenta a ingestão de ácido linoléico e PUFA total. Suplementação à base de amido ou óleo não afeta o teor de ácido mirístico ou palmítico no músculo *Longissimus dorsi*. Suplementação com óleo aumenta o nível de ácido esteárico e a relação n-6/n-3, mas diminui a percentagem de ácido linolênico no músculo de tourinhos Nelore em pastagem de *Brachiaria brizantha* cv. Xaraés durante a fase de terminação.

Palavras-chave: ácidos graxos, desempenho, glicerol, metano, Nelore, óleo

CHAPTER 1 - GENERAL CONSIDERATIONS

Projections indicate that the world population may increase by 1 billion over the next 12 years and reach 9.6 billion by 2050 (UN, 2013). Population growth and also the change seen in diet composition related to increased welfare levels (e.g. ALEXANDRATOS et al., 2006; VINNARI and TAPIO, 2009), with increased demand for animal products in developing countries, will increase future demand and natural resources utilization has been of critical interest to researchers, especially about the use of water, land and fertilizers (VAN HAM et al., 2013; LEACH et al., 2012).

In 2005, agriculture occupied about 38% of the global land area yielding an average agricultural land endowment of 0.76 ha per capita. Without technical progress and agricultural intensification and with current rates of population growth, agriculture would need an area equivalent to one half and two-third of the current terrestrial land area by 2030 and 2070, respectively, in order to maintain current food consumption levels per capita (FAO, 2011).

The global food system is experiencing profound changes as a result of anthropogenic pressures, including demographic and dietary changes, climate change, bioenergy development and natural resource constraints. These and related forces are also driving structural changes in the livestock sector, which has developed as one of the most dynamic parts of the agricultural economy (FAO, 2009).

Global consumption of dairy products and beef is projected to rise by well over 50% by 2050 (FAO, 2011). World meat consumption increased from 47 million tons in 1950 to 260 million tons in 2005, more than doubling the consumption per person from 17 to 40 kg/year (BROWN, 2006). In the face of competing demands for resources, ruminants play a key role in human food production in converting plant resources that humans cannot consume into high-quality food that humans can eat. The ability of ruminants to turn fibrous feed resources into edible animal food of high biological value is likely to become of greater significance in terms of global human food production as the population of the planet and demand for human-edible plant resources increases rapidly (DIJKSTRA et al., 2013).

Increased global demand for beef is being met from two main sources: rapidly expanding feedlot production; and intensification and spatial expansion of managed grazing systems. Both have significant regional and global environmental impacts (McALPINE et al., 2009). In Brazil, the majority of agricultural land in use is covered with pastures, almost 159 million ha, however most of it with low yields (IBGE, 2011). By allowing a fraction of current pasture area to accommodate the expansion of food and biofuel crops, intensification of existing pastoral systems is a strategy to avoid further loss of native vegetation. Thus increased animal production efficiency makes this a real possibility.

The area of pastureland dedicated to beef production in Brazil decreased from 174.5 Mha in 1980 to 159.8 Mha in 2006 (IBGE, 2011). In this same period meat production increased from 2.09 Mt to 6.89 Mt, following the increase in productivity from 11.9 to 43.4 kg/ha of carcass equivalent (MARTHA et al., 2012). The observed increase in animal performance further contributed to lower methane emission intensity (i.e. methane emissions per product unit). The land-saving effect due to productive gains in Brazilian beef sector was of 525 million hectares in the 1950 - 2006 period. But there is much room for improvement because the average Brazilian stocking rate was just 1.08 head/ha (MARTHA et al., 2012).

Increasing the efficiency of ruminant production is vital for food production to meet increasing demands. As livestock production grows and intensifies, it depends less and less on locally available feed and increasingly on feed concentrates. There is a shift from the use of low-quality roughages (crop residues and natural pasture) towards high-quality agro-industrial byproducts and concentrates (FAO, 2009).

In this sense, there is a new competition pattern, characterized by better adaptation of livestock due to strong demand, replacing the widespread availability of conventional products. A consequence of this new pattern of competition in the beef cattle industry is the use of agro-industrial byproducts in the diet of these animals, with the main objective to reduce production costs and, in addition, increase productivity, restore degraded areas, add income to the bio-energy production chain and reduce their environmental liabilities, providing appropriate conditions for future generations (MITLOEHNER, 2014).

This means that cereals can be largely replaced by these byproducts (MIRZAEI-AGHSAGHALI et al., 2011) and competition between human and animal nutrition can be decreased. Consequently, byproducts are becoming increasingly important in the food and fiber chain, because they are available for use as cattle feed at competitive prices compared to other commodities.

Crude glycerin is a byproduct of biodiesel agroindustry resulting from the formation of methyl esters of fatty acids from triglycerides. This byproduct has been reported as a potential energy source to partially replace starch-based ingredients in the diet, such as corn, because glycerol (an 85% constituent of crude glycerin) is converted to propionate in the rumen, decreasing the acetate:propionate ratio, and acts as a precursor for hepatic glucose synthesis (ABO-EL NOR et al., 2010; ABUGHAZALEH et al., 2011; AVILA et al., 2011; RAMOS and KERLEY, 2012).

Most research evaluating crude glycerin in ruminants has been based on performance measurements such as DMI, ADG, and G:F. The results show that glycerin can be used in ruminant diets up to 10% of diet DM without compromise intake and performance (DROUILLARD, 2012; PARSONS et al., 2009; SCHRODER and SUDEKUM, 2009). Hales et al. (2013) reported that propionate concentration was greatest in the diet with 10% glycerin at multiple time points postfeeding. Furthermore, earlier research has demonstrated that ruminal propionate concentrations were greater when a 45 *vs.* 0, 15, or 30% glycerin diet was added to continuous culture fermenters in place of corn (ABUGHAZALEH et al., 2011). If glycerin is primarily converted to propionate in the rumen, it is thought that glycerin may potentially decrease enteric methane emission and increase retained energy in the animal.

Globally, methane emissions account for 40% to 45% of greenhouse gas emissions from ruminant livestock, with over 90% of these emissions arising from enteric fermentation (FAO, 2006). Cattle are an important source of methane in many countries (e.g., Brazil) because of their large population and high CH_4 emission rate due predominantly of enteric fermentation and to a lesser extent, from manure storage. Although enteric fermentation is essential for the effective degradation of organic matter in the rumen (McALLISTER et al., 1996; BEAUCHEMIN et al., 2009), CH_4 has no nutritional value to the host and therefore represents a loss of up to 12%

of gross energy intake (JOHNSON and JOHNSON, 1995; BEAUCHEMIN et al., 2008).

Reduction of carbon dioxide to CH_4 is critical for efficient ruminal fermentation because it prevents the accumulation of reducing equivalents in the rumen (McALLISTER et al., 2015). Methane generated in the rumen is formed from hydrogen produced during the fermentation, and is formed by a group of microbes called methanogens, which form a subgroup of the domain Archaea (HUNGATE, 1967). Methane provides an essential means of H_2 removal, as H_2 in the rumen can inhibit hydrogenase activity and limit the oxidation of sugar if alternative means of H_2 disposal are unavailable (McALLISTER and NEWBOLD, 2008). Although CH_4 emission appears essential for efficient ruminal digestion, emissions also present an environmental concern because CH_4 is a potent greenhouse gas with a global warming potential (over 100 yr) 28 times that of CO_2 (IPCC, 2013).

Hydrogen is the most important energy source for methane-producing methanogens in the rumen, although formate (and to a limited extent, methanol) are also produced and used by methanogens. Different methanogen species use H_2 to reduce CO_2 to methane sequentially via a number of very similar pathways containing enzymes and co-factors not found in non-methanogens (THAUER et al., 2008).

The activity of the H_2-consuming methanogens in the rumen reduces the H_2 concentration to low levels, which allows the primary fermentation of the feed to proceed more rapidly. This means that the animal gains more fatty acids within a given time (WOLIN, 1979). High concentrations of H_2 in the rumen are expected to slow the activity of the microbes that ferment the feed, potentially slowing conversion to fatty acids (McALLISTER and NEWBOLD, 2008), and co-cultivation of H_2-producing and H_2-utilising microbes result in a more rapid fermentation (REES et al., 1995; MORVAN et al., 1996).

The primary factors affecting enteric methane emissions are the quantity and quality of the diet. As forage fiber content increases, nutrient digestion and passage rate decrease, increasing the predominate ruminal fermentation pathways and subsequent enteric CH_4 emission (CHIAVEGATO et al., 2015). Grazing management is a combination of several factors, such as stocking rate, density, and rest periods.

These factors define the relationship between herbage supply (ANIMUT et al., 2005) and forage quality, thus influencing herbage utilization efficiency, animal performance, and production per hectare (PINARES-PATIÑO et al., 2007).

According to classic study of Blaxter and Clapperton (1965), increased intake of poor-quality, less-digestible preserved forages have little effect on CH_4 emission when expressed on a DM intake basis. However, for feeds with higher digestibility, increased DM intake depresses the amount of CH_4 produced per unit of feed consumed (HAMMOND et al., 2009, HAMMOND et al., 2013). Cattle fed high- to moderate-quality forages lose 6.5% of GE intake as CH_4, while those fed high-grain diets may only lose 3% of GE intake as CH_4 (IPCC, 2006).

Therefore, grazing management may be used as a potential mitigant through grazing forages at the optimal maturity for increasing forage quality, allowing for adequate pregrazing herbage mass or intensive grazing (BEAUCHEMIN et al., 2008). The impact on CH_4 mitigation, when scaled per unit of animal product, should be typically greater when animals consume higher quality forage. Increasing quality or digestibility of forages will increase production efficiency and this will likely result in decreased CH_4 produced per unit of product (e.g., methane emission per kg of meat).

Thus, strategies that mitigate CH_4 emissions are not only environmentally beneficial, but also result in greater energy-use efficiency of feed by the animal. Bruinenberg et al. (2002) and Nkrumah et al. (2006) reported that a 25% reduction in CH_4 emissions could potentially increase body weight gain of growing cattle by 75 g/d based on the energy balances. Given the increasing demand for high-protein foods, emerging mitigation strategies will likely focus on reducing emissions per unit of animal product and not to reducing overall greenhouse gas emissions.

Consequently, significant effort has been directed toward improving our understanding of ruminal CH_4 formation and the identification of strategies that reduce methanogenesis (HRISTOV et al., 2013; KNAPP et al., 2014). Methane mitigation is effective in one of two ways: either a direct effect on the methanogens or an indirect effect caused by the impact of the strategy on substrate availability for methanogenesis, usually through an effect on the other microbes of the rumen (HOOK et al., 2010).

The components of ruminant diet, especially type of carbohydrate, are important for methane emission as they are able to influence the ruminal pH and subsequently alter the microbiota present (JOHNSON and JOHNSON, 1995). The digestibility of cellulose and hemicellulose are strongly related to methane emission, more so then soluble carbohydrate (HOLTER and YOUNG, 1992).

Carbohydrates are the major source of energy for rumen microorganisms and the single largest component (60-70%) of the ruminant diet. There are two broad classifications of CHO: the fibrous consist of elements found in the plant cell wall) and the nonfibrous (located inside the cells of plants and are usually more digestible than the fibrous CHO). However, even though pectin is a part of the cell wall, it is considered a nonfibrous CHO because compared to hemicellulose, the rumen microorganisms completely and rapidly ferment the pectin (NRC, 2001; ISHLER and VARGA, 2001).

Corn grains are used for food, feed, and the growing bio-fuel industry. This competition for corn has tightened the supply that is available for livestock feed and, as a result, has increased feed costs. The partial replacement of starch with cost-effective, low-starch, nonforage fiber sources represents a potential alternative to help overcome these issues. Previous research conducted on partial substitution of starch with nonforage fiber sources such as soybean hulls has led to the replacement of significant portions of starch from beef cattle diets (IPHARRAGUERRE et al., 2002; AIKMAN et al., 2006; JOSE NETO et al., 2015).

Soybean hulls, ingredient rich in pectin used in the diet of ruminants has a feeding value comparable with corn (HIBBERD et al., 1987; ANDERSON et al., 1988), and in some cases have alleviated adverse impacts on forage utilization often exhibited by cereal grains (KLOPFENSTEIN and OWEN, 1988; MARTIN and HIBBERD, 1990; GALLOWAY et al., 1993). Beneficial effects conferred by supplementation and supplementation type (starch-based vs. fiber based systems) can be altered by the quality of forage in the diet.

On the other hand, the starch component of the diet is also known to promote propionate formation, through a shift to amylolytic bacteria, and a reduction in ruminal pH, leading to a decrease in methanogenesis (VAN KESSEL and RUSSELL, 1996).

Starch is a polymer of glucose linked to another one through the glycosidic bond, which can be cleaved by enzymes. Two types of glucose polymers are present in starch: amylose and amylopectin. Amylose is a linear polymer consisting of up to 6000 glucose units with α-1,4 glycosidic bonds. Amylopectin consists of short α-1,4 linked to linear chains of 10–60 glucose units and α -1,6 linked to side chains with 15-45 glucose units (DEATHERAGE et al., 1955). However, starch is packaged in granules that are embedded in a protein matrix in the seed endosperm, which varies in solubility and resistance to digestion (KOTARSKI et al., 1992).

The extent and location of digestion of dietary carbohydrates affects the contribution to the energy or nutrient supplies to the animal, which alter types and amounts of products made available to the animal. In addition, altering the concentration and ruminal fermentability of starch in rations affects digestibility of starch (NGONYAMO-MAJEE et al., 2008), ruminal pH and fiber digestibility (FIRKINS et al., 2001), and the type, amount, and temporal absorption of fuel (e.g., acetate, propionate, lactate, glucose) available to ruminants (ALLEN, 2000).

The need to improve and optimize the efficiency of starch digestion is an important research focus in animal nutrition in ruminants a large proportion of starch from feed grains is fermented by microorganisms in the rumen, but a substantial amount of starch can be digested in the small intestine or fermented in the large intestine (OFFNER et al., 2003; FOLEY et al., 2006). Carbohydrates digested in the small intestine provide monosaccharides, notably glucose from starch. Ruminally, products of fermentation are much more diverse and come in the forms of gases, organic acids, and microbial mass (HALL and EASTRIDGE, 2014). Thus dietary starch fractions may be termed by site of digestion as ruminal fermentable starch, ruminal bypass starch, undigestible starch, and ruminally resistant starch (DECKARDT et al., 2013).

Research studies have examined ways to modulate the rumen degradability of starch, aiming to improve ruminant feed efficiency by changing the nature and amount of starch available to rumen microbiota, and/or shifting some starch digestion to the small intestine to improve its energetic efficiency, and moreover reduce enteric methane emission (HARMON et al., 2004; HUNTINGTON et al., 2006).

Compared with dietary fiber, starch fermentation in the rumen may result in reduced enteric CH_4 emission because fermentation of starch favors production of propionate (BANNINK et al., 2006), creating an alternative hydrogen sink to methanogenesis. Moreover, unlike fiber and sugar, a substantial fraction of potentially fermentable starch may escape from rumen fermentation to be digested enzymatically in the small intestine, adding to the energy supply of the animal without associated losses of energy with CH_4 emission (DIJKSTRA et al., 2011).

Another nutritional strategy to mitigate methane emissions from ruminants is the use of lipids. Inclusion of lipids in the diet decreases the amount of OM that is fermented in the rumen and therefore, reduces CH_4 emission (MACHMÜLLER et al., 2000; BEAUCHEMIN et al., 2009; MARTIN et al., 2010). Additionally, lipids can exhibit direct inhibitory effects on methanogens and protozoa (MACHMÜLLER et al., 2000; BEAUCHEMIN et al., 2009; MARTIN et al., 2010).

Numerous mitigation strategies have been investigated, each with varying impacts and differing durations of altering rumen microbial populations. Dietary strategies are most commonly employed, of which the most effective approach to inhibiting ruminal methanogenesis is inclusion of dietary medium- and long-chain saturated fatty acids, acting as a hydrogen sink through the hydrogenation of fatty acids (JOHNSON and JOHNSON, 1995; MACHMÜLLER et al., 2003; ZHOU et al., 2013).

Henderson (1973) reported that growth of M. *ruminantium* was inhibited by the addition of unsaturated and saturated medium-chain (C_{12} to C16) fatty acids. Further studies reported lauric acid (C_{12}) decreases cell viability of M. *ruminantium* (ZHOU et al., 2013). Therefore, the addition of fats to ruminant diets has also been recommended, as it similarly increases energy efficiency and hence reduces methanogenesis. However, greater concentrations of fats decrease methane production substantially, they often exert detrimental effects on fiber digestion, and consequently animal performance (PATRA, 2013).

In this sense, limited information is available on combined effects of different carbohydrate forms and oil source on animal performance and enteric CH_4 emissions from beef cattle on tropical pasture. The hypothesis of the present study is that soybean hulls could replace corn as a source of energy, and fat supplementation could reduce enteric CH_4 emissions without affecting performance of young Nellore bulls.

The objective of this study was to evaluate the combined effects of high- or low-starch supplements and oil on intake, digestibility, performance, carcass characteristics, and methane emissions of young Nellore bulls fed tropical pasture of *Brachiaria brizantha cv*. Xaraés during the growing and finishing phase.

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