UNIVERSIDADE ESTADUAL DE MARINGÁ
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SISTEMAS CAPRINOS ECOLOGICAMENTE INTENSIVOS E INCLUSÃO DE SAIS DE CÁLCIO DE ÁCIDOS GRAXOS DO ÓLEO DE SOJA NAS RAÇÕES DE CABRAS EM PASTEJO

Autora: Ludmila Couto Gomes
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Tese apresentada, como parte das exigências para obtenção do título de DOUTOR EM ZOOTECNIA, no Programa de Pós-graduação em Zootecnia da Universidade Estadual de Maringá – Área de Concentração: Produção Animal.

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TITULAÇÃO: Doutora em Zootecnia - Área de Concentração Produção Animal

APROVADA em 22 de agosto de 2014.

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Profª Drª Claudete Regina Alcalde
(Orientadora)

A
Deus...
pela força.

Aos
meus pais, Mauro e Arminda,
pelo amor e apoio eterno.

Aos
meus irmãos, Francisco, Marcos e Márcio,
pelo carinho e admiração.

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namorado, Rodrigo,
pelo incentivo e carinho.

Aos
amigos e familiares,
pelos momentos de grande felicidade.

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BIOGRAFIA

LUDMILA COUTO GOMES, filha de Mauro Alves Gomes e Arminda Maria do Couto Gomes, nasceu em Patos de Minas, Minas Gerais, no dia 15 de junho de 1987.

Em dezembro de 2008, concluiu o curso de Zootecnia pelo Centro Universitário de Patos de Minas (UNIPAM-MG).

Em março de 2009, ingressou no Programa de Pós-graduação em Zootecnia da Universidade Estadual de Maringá, obtendo o título de Mestre em Produção Animal em abril de 2011 obteve.

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De outubro de 2012 a setembro de 2013 foi contemplada com bolsa de doutorado-sanduíche pelo programa Ciências sem Fronteiras do Conselho Nacional de Desenvolvimento Científico e Tecnológico, para a realização do estágio no Institute Nationale de la Recherche Agronomique (INRA) - Centre de Clermont Ferrand, França.

No dia 22 de agosto de 2014, submeteu-se à banca de defesa da Tese e foi aprovada para receber a titulação de Doutora em Produção Animal pelo Programa de Pós-Graduação em Zootecnia da Universidade Estadual de Maringá.

ÍNDICE

RESUMO

O presente trabalho abrange dois domínios da zootecnia, um sobre o sistema de produção animal e outro da nutrição e produção de ruminantes. Sendo assim, a Tese é dividida em duas partes: a primeira sobre sistemas de produção de caprinos e a segunda sobre a produção de leite de cabras. PARTE I - Promover o desenvolvimento de sistemas de produção para formas mais sustentáveis, em especial, manter a produção sem prejudicar o meio ambiente, significa ser capaz de analisar esses sistemas em sua complexidade e dinâmica, ao mesmo tempo, fornecendo os meios para avaliar sua intensificação ecológica. Assim foi conduzido o estudo sobre a diversidade dos sistemas de produção de caprinos (SPC) em Livradois -Forez, França. Entrevistas semi estruturadas foram realizadas com 18 agricultores, amostragem selecionada para cobrir a diversidade de formas de produção neste território. O funcionamento dos sistemas pecuários foi analisado, olhando para as configurações do sistema e da combinação de práticas de gestão. Também foi analisada a importância do sistema dentro da trajetória de longo prazo da agricultura familiar. Para avaliar a intensificação ecológica em SPC, foi mobilizado os cinco princípios agroecológicos para o desenho de sistemas pecuários sustentáveis. A abordagem será apresentada e ilustrada com um estudo de caso. Assim é interessante compreender a diversidade do funcionamento dos sistemas caprinos e identificar o que promove ou limita o desenvolvimento destes sistemas em formas mais ecologicamente intensivas. PARTE II - A inclusão de sais de cálcio de ácidos graxos (SCAG) na dieta de ruminantes pode ser uma alternativa para aumentar a produtividade do sistema. Assim, cinco cabras Saanen multíparas, com cinco anos de idade e quatro cabras da raça Saanen primíparas, com três anos de idade foram utilizadas para avaliar os efeitos do SCAG sobre a ingestão, a digestibilidade, composição bioquímica do

sangue, o comportamento de pastejo e produção de leite. E, cinco cabras Boer x Saanen, fistuladas no rúmen foram utilizadas para avaliar os efeitos SCAG sobre os parâmetros ruminais. O uso de SCAG em dietas de cabras Saanen em lactação não limita a ingestão de matéria seca. No entanto, para as cabras multíparas, os valores de energia da dieta pode ser influenciado pelo nível de inclusão de SCAG na ração concentrada. Assim, a adição de SCAG pode ser usado como uma alternativa para cabras Saanen multíparas ou primíparas alimentadas em pastagens, sem grandes mudanças no comportamento de pastejo, composição bioquímica do sangue, a produção, composição e qualidade do leite. No entanto, a adição de SCAG apresentou efeito sobre a composição dos ácidos graxos do leite. Além disso, o pH e a concentração de nitrogênio amoniacal no rúmen teve efeito linear com os sais de cálcio de adição de ácidos graxos, como também houve efeito quadrático por horas após a alimentação. Enquanto, para a concentração dos ácidos graxos volátais no liquido ruminal não houve efeito pela adição do SCAG.

Palavras-chave: acidos graxos do leite de cabra, agroecologia, comportamento ingestivo diurno, lipideo inerte no rumen, n-alcanos

ABSTRACT

This paper presents two areas of animal science, one on the animal production system and other one on the nutrition and ruminant production. Therefore the thesis divided into two parts: the first on goat production systems and the second on the performance of dairy goats. PART I - Promoting the development of farming systems towards more sustainable forms, in particular maintaining production without harming the environment, means being able to analyse these systems in their complexity and dynamic, at the same time providing the means to assess their ecological intensification. Thus, a study have done on the diversity of goat farming systems (GFS) in Livradois-Forez, France. Semi-structured interviews were conducted with 18 farmers, a sample selected to cover the diversity of livestock forms in this territory. The operation of livestock systems was analysed by looking at the system configurations and the combination of management practices. The place of the goat system within the family farm's long term trajectory was also analysed. To assess the ecological intensification in GFS, the five agroecology principles were mobilized for the design of sustainable livestock systems. Its approach application was presented and illustrated with a case study. The interest of understanding the diversity of livestock forms was showed and was identifed what promotes or limits the development of these systems into more ecologically-intensive forms. PART II – The inclusion of calcium salts of fatty acids (CSFA) in the diet of ruminants may be an alternative to increase system productivity. Five multiparous Saanen goats, with five years old and four primiparous Saanen goats, with tree years old were used, to assess the effects of CSFA on intake, digestibility, blood biochemical composition, grazing behaviour and milk production, also five crossbred Boer x Saanen goats, rumen fistulated were used to assess CSFA effects on

the parameters of rumen.The addition de CSFA on concentrated diets of lactating Saanen goats does not limit the dry matter intake. However, for the multiparous goats, the energy values of diets can be influenced by the level of CSFA. Thus, the addition of CSFA can be used as an alternative to fed multiparous or primiparous Saanen goats in the grassland without drastic changes in the grazing behaviour and blood biochemical compostion, the milk yield, milk composition and milk quality. However the addition of CSFA had a little effect on fatty acids composition. Also, the pH and ammonia N concentration in the rumen had a linear effect with the calcium salts of fatty acids addition, and there was a quadratic effect for hours after feeding. And the no effect was observed for volatile fatty acids molar proportions in rumen fluid after grazing of goats fed by experimental diets.

Keywords: agroecology, diurnal ingestive behaviour, farming systems, goat milk fatty acids, n-alkanes, rumen-inert fat

I- INTRODUÇÃO

O presente trabalho abrange dois domínios da zootecnia, sendo um sobre o sistema de produção animal e outro sobre a nutrição e produção de ruminantes. Desse modo, a Tese é dividida em duas partes: sistemas de produção caprinos (PARTE I) e produção de leite de cabras (PARTE II).

As cabras são animais profundamente integrados na cultura e tradições das sociedades, sendo um modelo de adaptação ao ambiente socioeconômico e natural local. Assim, os sistemas de produção caprinos apresentam meios para um modelo de pecuária sustentável e produtiva. Neste aspecto, a Parte I objetiva identificar os diferentes tipos de funcionamento de sistemas de caprinos na França e os ligar a formas de intensificação ecológicas; assinalando o que favorece produção animal e o respeito ao meio ambiente concomitantemente. Tem como hipótese científica que os produtores rurais racionalizam diferentemente seu sistema em função dos recursos disponíveis a eles e que a otimização da utilização dos recursos reflete no funcionamento do sistema de produção e na forma de intensificação ecológica.

Para que o estudo de sistemas caprinos ecologicamente intensivos se desenvolva é fundamental o desenvolvimento, pelos especialistas de cada área, práticas de manejo que favorecem tanto a produção animal como a preservação do meio ambiente. Logo, estudos na área de nutrição, produção, melhoramento genético, sanidade e bem-estar animal são importantes para o aperfeiçoamento de novas práticas de manejo do senso da intensificação ecológica.

Estudos de inclusão de sais de cálcio de ácidos graxos do óleo de soja na dieta de ruminantes representam uma alternativa para aumentar a produtividade do sistema e preservar o meio ambiente. A inclusão destes sais de cálcio tem sido utilizada em

pesquisas, como meio de aumentar a produção e a qualidade do leite, bem como a eficiência, e a diminuição da produção de metano.

Porém, com base nas respostas obtidas pelos estudos publicados até o momento sobre a suplementação de cabras com sais de cálcio de ácidos graxos de cadeia longa, conclui-se que este é um potencial alimento para a suplementação de cabras em lactação. No entanto, os resultados ainda são controversos, exigindo novas pesquisas para elucidar esses resultados.

As pastagens apresentam grande importância territorial no Brasil, sendo a produção intensiva de leite de cabra a pasto uma alternativa para otimizar a utilização desses recursos naturais. Todavia, para que o sistema seja produtivo, sustentável e econômico é preciso manejar racionalmente as pastagens, para viabilizar a produção de leite e/ou carne de qualidade e a preços competitivos para atender as exigências de mercado.

Para a parte II a hipótese científica avaliada consiste em que a adição de sais de cálcio de ácidos graxos do óleo de soja na ração concentrada de cabras Saanen em pastagem (*Cynodon nlemfuensis*) influencia positivamente no valor nutritivo das dietas, no desempenho produtivo, no metabolismo e na fermentação ruminal. Ademais a resposta animal é diferente em função da categoria animal (cabras multíparas ou primíparas).

II- OBJETIVOS

Objetivou-se neste estudo:

Descrever e compreender a diversidade dos sistemas de produção de caprinos leiteiros na região do Livradois-Forez – França, além de identificar as diferentes formas de intensificação ecológicas que podem estar ligadas a estes sistemas.

Avaliar o efeito da adição de sais de cálcio de ácidos graxos do óleo de soja na ração concentrada sobre o valor nutritivo das dietas, o desempenho produtivo, a composição e qualidade do leite de cabras Saanen lactantes, multíparas e primíparas em pastejo; bem como o efeito sobre os parâmetros de fermentação ruminal.

III - Revisão de literatura: Funcionamento de sistemas de produção de caprinos e formas de intensificação ecológica

Os caprinos são animais presentes na cultura e tradições das sociedades, sendo um modelo de adaptação ao ambiente socioeconômico e natural local. Assim, os sistemas de produção de caprinos apresentam meios para modelo de pecuária sustentável e produtiva.

1. Análise do funcionamento de sistemas de produção animal

O sistema de produção animal surge de um projeto humano que define a extensão da ligação entre os elementos que o compõem (Landais, 1987). Desse modo, um sistema de produção animal pode ser definido como conjunto de elementos em interação dinâmica organizado pelo homem em função de seus objetivos para produzir (leite, carne, couro, peles, etc.) e reproduzir o conjunto de animais domésticos, valorizando e renovando vários recursos (Dedieu et al., 2008b).

A gestão do sistema de produção é, portanto, visto como sistema complexo controlado pelo produtor. O homem deve ser considerado tanto como gestor, como ator, trabalhando sobre o real; ou seja, o produtor realmente coloca as suas decisões, por meio de atividades consistentes e concluídas que são chamadas de práticas de manejo; tendo os produtores "boas razões para fazer o que fazem" (Petit, 1981).

A modelagem dos sistemas de produção animal é baseada na fragmentação do sistema em dois subsistemas funcionais: o subsistema de gestão, informações e decisões do produtor, e o subsistema biotecnológico de elaboração da produção do rebanho. Esses dois subsistemas são conectados pelas práticas de manejo e *feedback* sobre a condição dos animais e dos recursos (Landais, 1987; Dedieu et al., 2008b). Então, a análise de como o sistema de produção animal funciona consiste na observação das práticas de manejo e combinações de práticas para identificar as motivações que estão por detrás destas (Landais et al., 1988) ou, na avaliação do projeto de produção para revelar a estratégia de gestão realizada pelo produtor.

De acordo com essa definição, as práticas de manejo se dividem em três grupos principais: gestão do rebanho, gestão dos recursos e gestão para assegurar a adequação entre a dinâmica do rebanho e dos recursos no tempo (Dedieu et al., 2008b). No contexto dessa definição, centrada no desenvolvimento da produção, diversas variações são possíveis, dependendo das práticas de manejo utilizadas para descrever e analisar o

sistema de produção animal. Enquanto alguns pesquisadores se atentam especialmente às práticas de manejo do rebanho e da superfície, outros se concentram mais na dimensão, no projeto de produção e nos objetivos dos produtores.

De acordo com Moulin et al. (2001), o sistema de produção animal é visto como a articulação entre um projeto de produção, as práticas de manejo e a dimensão do rebanho com a área destinada a produção animal. Assim, são articulados para alcançar o objetivo de produção (Dedieu et al., 2008a).

As práticas de manejo e suas combinações são fatos reais e facilmente observáveis (Milleville, 1987), e são o objeto central para o estudo dos sistemas de produção animal. Desse modo, este sistema é considerado como a união de práticas de manejo resultantes do conjunto estruturado das escolhas do produtor para cumprir os seus objetivos, considerando várias restrições para a estrutura do sistema e as características do seu ambiente. Portanto, as práticas implementadas por um produtor em todo seu sistema de produção são mutuamente dependentes (Lasseur et al., 2004).

As categorias de práticas de manejo são comumente distinguidas em: *i*) práticas relacionadas a produção de forragem, ou seja, a gestão e manutenção da superfície, as reservas de alimento e a organização do pastejo; *ii*) práticas relacionadas a gestão e renovação do rebanho, todas as operações realizadas pelo homem sobre os animais para garantir a sua manutenção e garantir o desempenho esperado, bem como todas as operações de renovação da composição do rebanho (tamanho e aptidão); *iii*) práticas relacionadas com a valorização dos produtos, todo o processamento de produtos primários.

Recentemente, Darnhofer et al. (2012) definiram que nos sistemas de produção animal se concentra na interface entre as dimensões humanas, “Produtor”, e os aspectos técnicos da propriedade “Fazenda” e “Ambiente” (Figura 1). Assim, ao analisar um sistema de produção, os três conjuntos de fatores, precisam ser considerados: a dimensão humana, ou seja, o produtor rural e membros da família com suas preferências individuais, projetos e história; a propriedade com seus bens e recursos e o ambiente constituído por redes sociais, oportunidades econômicas, incentivos políticos e contexto biofísico.

Do ponto de vista da organização do trabalho (mão de obra), o sistema de produção se define como a articulação no tempo do manejo e dimensão da propriedade, das instalações e equipamentos, do coletivo de trabalho e das atividades principais da propriedade (Madelrieux e Dedieu, 2008; Dedieu et al., 2010).

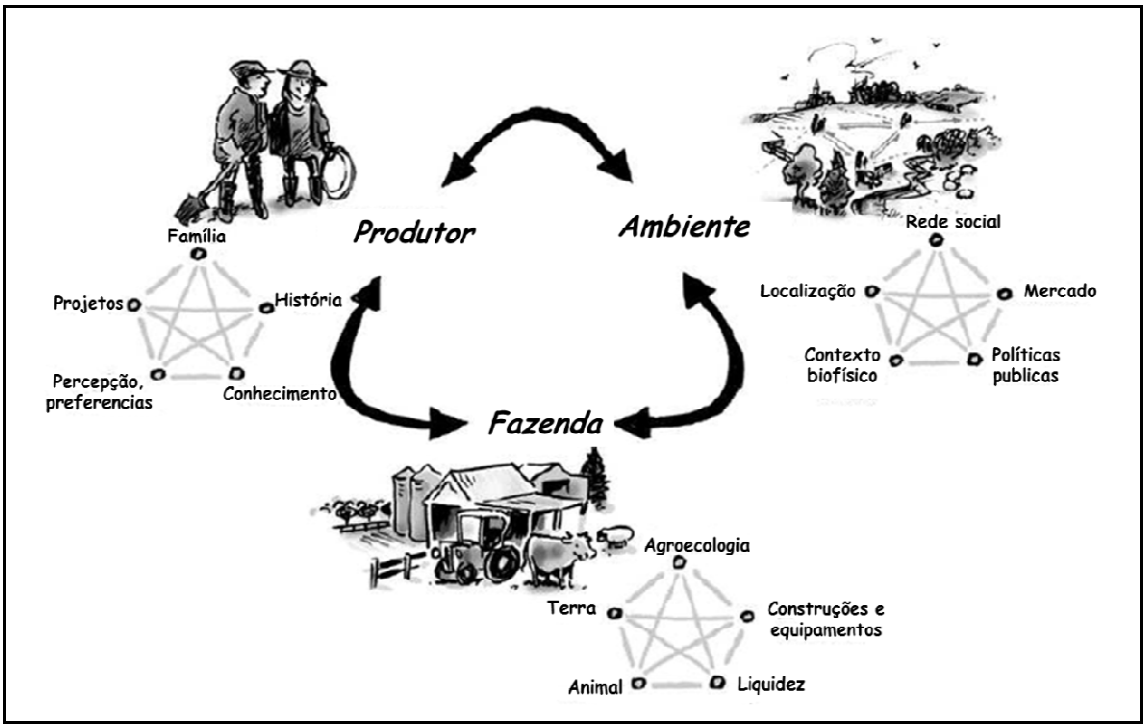

Figura 1
Interface entre as dimensões humanas, técnicas e ambientais da atividade agrícola. Fonte: Adaptado de Darnhofer et al. (2012).

Considerando a organização familiar no sistema de produção animal, Terrier (2013) definiu o sistema família-pecuária; que é a articulação dinâmica entre seis polos: *(i)* projeto de produção, *(ii)* dimensão (do rebanho e da superfícies), *(iii)* instalações e equipamentos, *(iv)* o manejo do rebanho e da superfícies, *(v)* coletivo de trabalho e, *(vi)* o sistema de atividades da família do produtor.

2. Sistemas de produção de caprinos leiteiros

A produção animal, como todas as produções agrícolas enfrentam desafios complexos da sustentabilidade (Dedieu et al., 2011). A criação de cabras também está sujeita a estes desafios (Peacock, 2005; Devendra, 2007; Dubeuf, 2011), mas apresenta vantagens em relação a outras espécies animais, por causa do seu potencial e sua adaptabilidade. A maior parte dos caprinos no mundo é criada em sistemas tradicionais e poucos artificializados usando baixas quantidades de insumos (Ahuya et al., 2005; Iñiguez, 2011), contribuindo fortemente para a economia familiar e a cultura regional (Alexandre et al., 2012). Em menor parte, os caprinos são criados em sistemas intensivos de produção cujo foco principal é a comercialização do produto com alto valor agregado, o queijo do leite de cabra.

Para analisar e compreender o funcionamento dos sistemas de produção de cabras leiteiras é importante desenvolver abordagem integrada e holística do sistema para permitir destacar os aspectos-chave do progresso de produção de leite de cabra. Assim, é importante conhecer aspectos da alimentação, reprodução, sanidade e produção das cabras.

Graças às suas características naturais, a cabra é capaz de se adaptar a diferentes sistemas de produção e a diferentes ambientes (Castel et al., 2010). Na União Europeia os caprinos são criados principalmente nas áreas menos favorecidas dos países do Mediterrâneo, em que há vastas terras marginais com pastagens ideais disponíveis para este tipo de produção animal (Castel et al., 2003; Nahed et al., 2006; Rancourt et al., 2006; Usai et al., 2006). No Brasil a caprinocultura está localizada principalmente em regiões de semiárido (90% do rebanho nacional) em que os sistemas de produção de leite de cabra são extensivos ou semi-intensivos com a vegetação nativa (Caatinga) como base da alimentação (Costa et al., 2008; Lopes et al., 2008). No entanto, a região Sudeste, em que predomina inteiramente o sistema de produção intensivo e confinado (Gonçalves et al., 2008; Silva et al., 2012), destaca-se pela produção comercial de 21% do total de leite produzido no país, mesmo dispondo de apenas 3,5% do efetivo caprino do Brasil.

Pelo comportamento alimentar e capacidade digestiva, a cabra é capaz de explorar pastagens arbustivas naturais (Ramirez, 1999; Basha et al., 2012), e valorizar vários tipos de coprodutos (Alexandre et al., 2010), permite também associar as cabras a sistemas agrossilvopastoris (Degen, 2007; Iñiguez, 2011), a sistemas agrícolas periurbanos (Diogo et al., 2010; Dedieu et al., 2011), como também é possível a criação de cabras confinadas, em sistemas de produção intensiva de grande escala (Castel et al., 2011).

A reprodução é um ponto-chave para controlar todo o sistema de produção. Por isso, é fundamental a capacidade dos produtores de gerenciar a reprodução das cabras de acordo com seus próprios objetivos, a disponibilidade de alimentos e a demanda do mercado (Peacock, 1998).

De acordo com Alexandre et al. (2012) os sistemas de produção de cabras devem conciliar o aumento da produtividade pela intensificação de utilização da superfície, pela utilização dos recursos locais disponíveis e pela melhora do desempenho animal, como a adoção de técnicas de produção que garantam a sustentabilidade ambiental, econômica e social do sistema.

3. O conceito de intensificação ecológica

A pecuária é um componente importante da vida social, da economia familiar e da gestão dos ecossistemas. Entretanto, controvérsias relativas aos impactos da pecuária sobre o meio ambiente assolam a contemporaneidade em decorrência dos componentes negativos, como a produção de emissões de gases de efeito estufa (Steinfeld et al., 2006), mas em razão dos serviços positivos, como o sequestro de carbono e preservação da biodiversidade em áreas de pastagem natural (Steinfeld et al., 2010). Ademais, na atualidade debates sobre o futuro da pecuária envolvem preocupações sobre a alimentação da população mundial em crescimento, a qual em 2050, por razões de luta contra a subnutrição e a desnutrição, e provavel aumento do padrão de vida irá reforçar a demanda por produtos de origem animal em 100% (Agrimonde, 2010). De acordo com a Organização das Nações Unidas (ONU), essa demanda pelo dobro dos alimentos deve ser produzida pela mesma área que hoje é utilizada para produção agropecuária, e segundo a FAO (Organização das Nações Unidas para Agricultura e Alimentação) 70% desse fornecimento adicional de alimentos deverá vir do uso de tecnologias que melhorem a eficiência dos sitemas de produção.

O debate sobre a pecuária, em especial de ruminantes, não pode se limitar a estas considerações globais. Na verdade, a pecuária também contribui para o desenvolvimento sustentável das zonas rurais. Assim, é tanto um produtor quanto um utilizador dos serviços ecológicos (Gibon, 2005; Quétier et al., 2007; Zhang et al., 2007). Para Bommarco et al. (2013) a crescente demanda de produtos agrícolas aumentará a pressão para intensificar ainda mais a produção agrícola, ao passo que os impactos ambientais negativos deverão ser minimizados.

O conceito de intensificação ecológica (IE) é apresentado para sugerir possíveis respostas para o duplo desafio de diminuir o impacto ambiental e de maximizar a produção animal a nível global, incorporando a dimensão local (Griffon, 2006; Steinfeld et al., 2010). Este conceito foi usado pela primeira vez em meados da década de 1990, definindo como o aumento da produção agrícola mantendo padrões aceitáveis de qualidade ambiental (Cassman, 1999). Em estudos mais recentes, a IE é definida como a evolução da agricultura que permite produzir sem agredir o meio ambiente e utilizando melhor as funcionalidades dos ecossistemas, em outros termos, uma agricultura mais produtiva e mais durável (Bonny, 2011; Griffon, 2013).

Assim, a intensificação ecológica é definida por duas características: a intensificação, referente ao conceito de produzir mais por hectare, e de forma

ambientalmente correta. Logo, traduzida como a otimização da utilização dos insumos, ou seja, pode ser tanto a intensificação da produção de forma racional que diminui a produção de dejetos e gases do efeito estufa, quanto a agregação de valor ao produto pela agricultura orgânica.

Para avaliar a intensificação ecológica em sistemas de produção animal, é importante posicionar a intensificação ecologia em relação à agroecologia. Visto que, a análise dos processos ecológicos envolvidos na produção agrícola é o centro da agroecologia, disciplina científica definida como o estudo integrado da ecologia de todo o sistema alimentar, que abrange as dimensões ecológica, econômica e social (Francis et al., 2003). A agroecologia e a intensificação ecológica se diferenciam pela noção de intensificação.

No entanto, para promover o desenvolvimento de uma pecuária mais produtiva e que respeite o meio ambiente é preciso analisar os sistemas de produção animal em sua complexidade, oferecendo meios para avaliar a sua posição em relação à gestão mais "ecologicamente intensiva". Com isso, quadros analíticos de sistemas de produção animal, popostos na década de 1980, devem ser adaptados a esta questão. Pórem, a intensificação ecológica é movimento amplamente documentado em grandes culturas (Griffon, 2010; Doré et al., 2011) e com poucos estudos equivalentes para a produção animal. Tornando, desse modo, importante documentar a intensificação ecológica para a produção animal.

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IV- An approach for assessing the ecological intensification of livestock systems

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Keywords: agroecology, framework application, goat, sustainable livestock, system configurations

Abstract

Promoting the development of farming systems towards more sustainable forms, in particular maintaining production without harming the environment, means being able to analyse these systems in their complexity and dynamic, at the same time providing the means to assess their ecological intensification. The approaches to these livestock systems have to be adapted to this aim. This is what we have done as part of a study on the diversity of goat farming systems (GFS) in Livradois-Forez, a small region of fairly low mountains in France. Semi-structured interviews were conducted with 18 farmers, a sample selected to cover the diversity of livestock forms in this territory. We analysed the operation of livestock systems, looking at the system configurations (dimensions, buildings and equipment, labour force, combinations of farming activities, production project) and the combination of management practices (crops, herds and valorisation of products). We also analysed the place of the goat system within the family farm's long term trajectory. To assess the ecological intensification (EI) in GFS, we mobilized the five agroecology principles for the design of sustainable livestock systems proposed by Dumont et al. (2013): (i) adopting management practices aimed at improving animal health, (ii) decreasing inputs for production, (iii) decreasing pollution by optimizing the metabolic functioning of the farming system, (iv) enhancing diversity within animal production systems to strengthen their resilience and (v) preserving biological diversity in agro-ecosystems by adapting management practices. We present this approach and illustrate its application to our case study. We show the interest of understanding the diversity of livestock forms and identify what promotes or limits the development of these systems into more ecologically-intensive forms. In conclusion, this approach has allowed identifying four type of goat farming systems (GFS) in Livradois-Forez corresponding to different ecological intensification profiles, and identify that promotes or limits the development of GFS into more EI forms is the avaible land area and its features and depending on the conditions of farmer establishment.

1. Introduction

Nowadays the ecological intensification (EI) concept is being highlighted to suggest possible answers to the dual challenge of improving environmental impacts and increasing livestock production at global level, whilst at the same time incorporating the local dimension (Griffon, 2006 ; Steinfeld et al., 2010). Ecological intensification is an evolution of agriculture that aims to produce without harming the environment and to make better use of ecosystem functions (Bonny, 2011 ; Griffon, 2013). Although this movement is widely documented in field crops (Griffon, 2010), it is less well-documented in animal production.

The development of these new forms of farming systems needs to improve the integration of ecological processes into the operation of livestock systems. To foster such a development, we must be able to analyse these systems in their complexity and their dynamic, at the same time giving ourselves the means to assess their ecological intensification. Analytical frameworks of farming systems, designed in the 1980s must be adapted for this purpose. There are several proposals in literature to qualify cropping systems with reference to ecological intensification (Cassman, 1999 ; Zhang et al., 2007 ; Doré et al., 2011 ; Rusinamhodzi et al., 2012 ; Hochman et al., 2013), however, for livestock systems there are fewer equivalent studies.

We propose an approach for analysing the ecological intensification (EI) of livestock systems. This approach should make it possible to describe and understand the diversity of livestock forms and identify what promotes or limits the development of these systems into more ecologically-intensive forms. This paper presents an approach and its application to assess the diversity and pathways of evolution of goat systems in Livradois-Forez, a small agricultural region in central France.

2. Theoretical basis for the construction of the approach

Our approach is constructed on three concepts: the farming system (Gibon et al., 1999), the framework of the farming activity (Terrier, 2013) and agroecology for animal production (Dumont et al., 2013). These three concepts were structured in an approach that allows two frameworks to be applied consecutively: the first to characterise the operation of livestock systems, and the other to assess their ecological intensification.

2.1 Approach to livestock farming systems

Farming systems come from a human project that defines the extension, linking its constituent elements (Landais, 1987). It can be defined as "a collection of elements in dynamic interaction, organised by man according to his objectives, to produce milk, meat, hides, skins, manure, etc., from domesticated animals which reproduce themselves, by using and renewing a variety of resources" (Dedieu et al., 2008). For Moulin et al. (2001), the farming system is the linkage between a production project and the dimensioning and management of surface areas and herds. The analysis of how a livestock system functions consists: i) in identifying their 'underlying motivations' (Landais et al., 1988) from the observation of practices and combinations of practices, or of the farmer's production project, and ii) in revealing the farmer's management strategy (Landais et al., 1988).

Our framework for analysing how the livestock system functions takes its inspiration from that of Terrier (2013) which takes account of the family dimension of the farm and the plurality of forms of agriculture today (multi-active or not, managed by a couple, by just one permanent worker,- the partner working outside the farm etc…). We thus define the operation of a livestock system as an association among family and farm system configurations (available dimensions and structures, labour force), the chosen production project (animal production type, investment for processing and marketing the products, and combination of economic activities) and the combination of management practices (crops, herds and valorisation of products). The trajectory of the farmer (who manages the goat herd) and of the farm has been introduced to take into account the dynamic aspect of this operation (see Figure 1).

2.2 Approach to ecological intensification

Ecologically-intensive agriculture, unlike organic farming, does not have a set of specifications that provides a framework for production practices; it is a progressive approach which brings many practices into play (Griffon, 2013). To assess the ecological intensification of the operation of livestock systems, we rely on the framework proposed by Dumont et al. (2013) to characterize ecology-based alternatives for animal production systems. These authors identified the processes to be optimized for sustaining yields, while minimizing the negative environmental impact of animal production systems, which corresponds to the objectives of ecological intensification. These processes need to be optimized according to the five major agroecology

principles in reference to those set out by (Altieri, 2002) : (i - Health) adopting management practices aimed at improving animal health, (ii - Inputs) reducing the inputs needed for production, (iii - Pollution:) decreasing pollution by optimizing the metabolic functioning of farming systems, (iv - Diversity) enhancing diversity within animal production systems to strengthen their resilience and (v - Biodiversity) preserving biological diversity in agro-ecosystems by adapting management practices. We used these five principles to describe the practices implemented on the farms and build an "ecological intensification" profile for each of them (cf below in Methodology for more details).

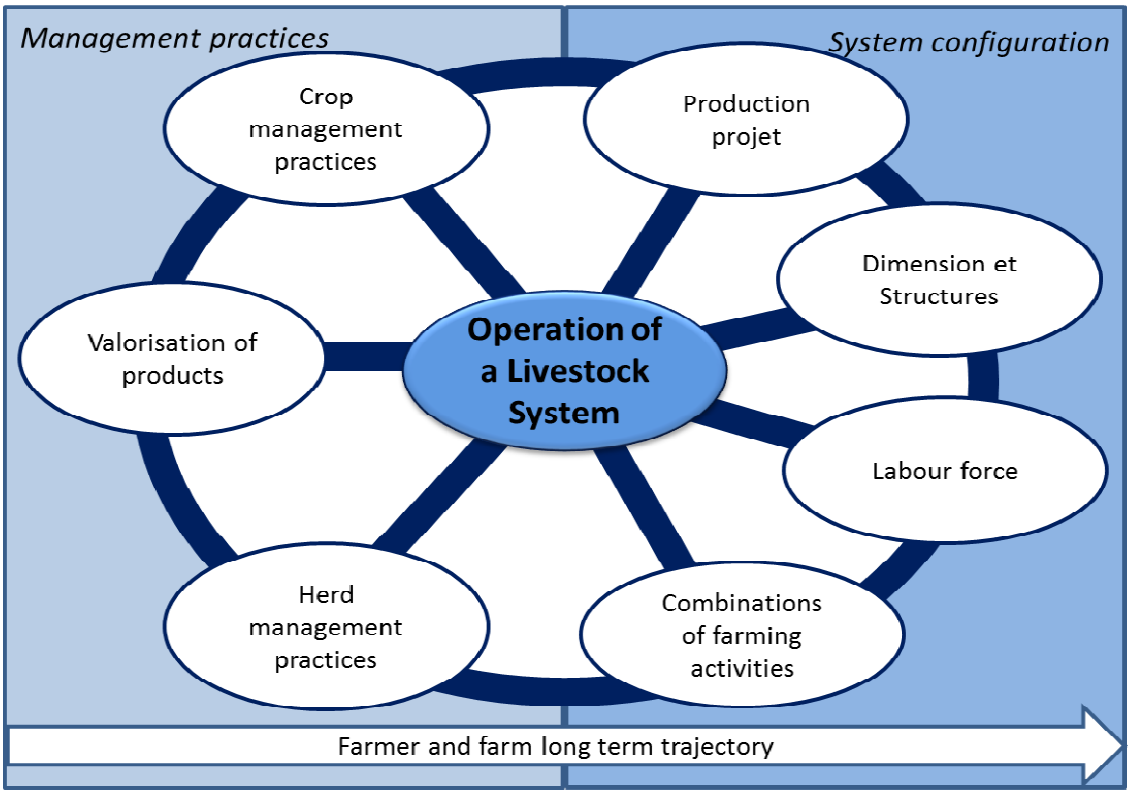

Figure 1. The framework for analysing the operation of a livestock system.

3. Methodology: Application of the approach in goat farms in Livradois-Forez

The study was conducted with goat farmers in Livradois-Forez, a rural territory in an area of low mountains, to the east of the Massif Central in France. The goat farms are scattered and form a minority in the territory, but they are of interest for this territory and the ecological intensification of its livestock activity. In fact this type of livestock farming often makes good use of marginal areas with limited potential, of little interest to the cattle farms that form the majority in this region. These systems do not require

much land and offer opportunities for low-volume production with high added value because of processing on the farm and sales on local markets. Young farmers find this type of system easier to set up outside the family framework, and many more of them work under this system than in the other sectors. Surveys were conducted with eighteen of the 34 goat farms identified in the Puy-de-Dôme region in this territory. These goat farms were selected to cover as large a diversity of systems as possible in terms of dimension (surface area and herd), goat grazing, production orientation (milk or cheese) and association with other animal units. Semi-structured interviews addressed the trajectory of farmers and farms, the management practices of herds and lands and their justification, the forms of marketing and valorisation of products, and farmer perspectives.

These data were used to build variables which enable us to: i) characterise the operation of each livestock system according to the first framework (cf 2.1) ii) assess its ecological intensification according to the second framework (cf 2.2).

To construct the variables a repertory grid was used as a tool to make explicit rankings of the cases according to criteria of differentiation “modalities” (Girard, 2006) and, then, each farm has been linked with one "modalities" for each variable. 30 variables were used to characterise the operation of each system (see Table 1). Among the possible variables we included only those which had different values among farms.

A typology was carried out on these active variables. Bertin’s graphical method (Bertin, 1977) was used for bringing similar farms closer together visually by successive permutation of rows (active variables) and columns (the farms studied). The types of systems identified correspond to specific combinations of these variables, reflecting specific logics of operation that are characterized as prototypes (Girard, 2006). We used the trajectory of the farmer (who manages the goat herd) and of the farm and other information gathered during the interviews relating to the way in which the system had been constructed over time, to complement our description of the types of operation.

To assess the ecological intensification of the operation of livestock systems, we rely on the framework proposed by Dumont et al. (2013) to characterize ecology-based alternatives for animal production systems. To characterize the ecological intensification profile of each system, five variables were built, one for each principle (Health, Inputs, Pollution, Diversity and Biodiversity). Each practice was considered as a binary variable (yes = 1, no = 0) to homogenize the measurement units; and after,

with the number of "yes" answers we created the indicaterus of degree of commitment to the principles of agro-ecology. Each variable allowed the system to be positioned on an agroecological principles gradient, according to its level of response to the corresponding principle. This gradient was summarized in 3 synthetic modalities: low, medium and high. Each farm was rated as low, medium or high mode for each of the 5 variables (principles) depending on whether it was implementing less than 33%, between 33 and 66% or more than 66% of the practices listed for the corresponding principle. We defined the ecological intensification profile of each farm type as the combination of five variables (five principles), which was represented by Radar diagrams.

The system typology was then cross-referenced with the characterisation of the EI profile. Thus for each type of system we built an EI profile, retaining for each variable (principle) the modality which was the most represented among the farms of the type.

4. Results

4.1 Sampling characteristics

Our sample has a wide variety of dimensions of the utilized agricultural area (UAA) with an average of 62 hectares, but it varies from 1 ha to 254 ha, and the number of goats from 12 to 195 with an average of 65 goats. The installations outside the family framework are numerous (50%), and the working groups are diverse, with single farmers and couples as well as associations of 2 to 3 people. The majority of farms chose to process goat's milk to make cheese, sometimes mixed with cow's milk. Only four farms deliver all of their goat's milk to a dairy. The majority of farms (89%) associate the goat unit with another livestock unit (beef cattle, dairy cows, sheep, horses, poultry or pigs). There is a high diversity in terms of resources used, with systems entirely on feedlot which purchase all food for their goats, and others based on significant use of pasture with varying degrees of food self-sufficiency.

4.2 Four types of goat operation systems…

The typology in 18 goat farms identified four types of operation systems that are described as: 1) Resource-centred; 2) Goat-centred; 3) Cow-centred; and 4) Limited land area, which are discriminated by the importance of the goat activity in the farms and the mobilization of available resources (see Table 1).

Table 1. Description of the type of operation of goat livestock systems in Livradois-Forez, France

	Resource-centred	Goat-centred	Cow-centred	Limited land area
Number of Farmers	*5*	*6*	*2*	*4*
A. System configurations				
A.1. Trajectory of the farmer and the farm				
1. Motivation to be a farmer	Take over the place	Passion, challenge	Find a place	Passion, challenge and change of life
2. Date of installation	Between 5 and 20 years	More than 20 years	More than 20 years	Less than 5 years
3. Installation mode	Family framework	Outside family framework	Family framework	Outside family framework
4. Dynamic evolution of surface area	Without enlargement	Without enlargement	Enlargement	Developing
5. Technical knowledge	Parent to child	Training and dialogue with other farmers	Parent to child	
A.2. Dimensions and structures				
6. Utilized agricultural area (UAA)*	87 ha	21 ha	197 ha	13 ha
7. Labour force	2 people (couples or associations)	Pair	Association of 3 people	Pair
8. Use of hired labour	No employee	Employee	Employee	No employee
9. Number of goats*	84	59	31	75
A.3. Production project				
10. Main orientation of goats	Milk delivery	Processing of milk	Processing of milk	Processing of milk
11. Main herds	Goat and beef cattle	Goat	Dairy cows	Goat
12. Different animal units	Beef cattle, Sheep or Poultry	Pigs, Horses, Sheep, or Dairy cows	Dairy cows	Horses, Sheep, Dairy cows, Poultry or Specialized
13. Complementarity between species**	Resources and Territory	Resources and Territory	Resources and Product	Product
14. Other non-agricultural activities	No other activities	Other activities	No other activities	No other activities
15. Annual milk production per goat*	800 litres	610 litres	775 litres	690 litres
B. Management practices				
B.1. Land management practices				
16. Main forage area (MFA)*	90%	98%	92%	100%
17. Permanent grassland*	58% of MFA	88 % of MFA	42% of MFA	100% of MFA

	Resource-centred	Goat-centred	Cow-centred	Limited land area
18. Presence of temporary grassland	Temporary grassland	Temporary grassland in half of the cases	Temporary grassland	No temporary grassland
19. Presence of cereals	Farm consumption	No cereals	Farm consumption	No cereals
20. Fertilization	Manure	Manure	Manure and Fertilizer	Manure
B.2. Goat feeding system				
21. Food self-sufficiency	Forage	Forage	Forage	No self-sufficiency
22. Grazing	60% of the farms	100% of the farms	50% of the farms	50% of the farms
23. Grazing goats area*	23% of the MFA	59% of the MFA	14% of the MFA	58% of the MFA
24. Grazing goats stocking rate	2.4 goats.ha^{-1}	3.5 goats.ha^{-1}	2.4 goats.ha^{-1}	2.4 goats.ha^{-1}
25. kg of concentrate per goat per year*	304	201	310	180
B.3. Goat management practices				
26. Milking frequency	twice daily	temporarily once daily	2 times daily	temporarily once daily
27. Practice of drying off	Sudden drying off	act on the milking and feeding	act on the milking and feeding	act on the milking and feeding
28. Number of batches for reproduction	1 batch	2 to 3 batches	1 batch	1 batch
B.3. Valorisation of products				
29. Channels of trade	Indirect	Direct and indirect	Direct and indirect	Direct
30. Cheese diversity	No cheese	Pure goat cheese lactic and rennet	Lactic cheeses mixed with goat's and cow's milk	Pure goat cheese

*average values of all farm for the type of operation of goat livestock systems

**Complementarity between species: Territory: for the use of land (e.g. field proximity for goats and less close for lactating cows); Resources: for the use of resources (e.g. the best hay for goats); Product: for making mixed cheese and commercialization.

In the first type called ***"resource-centred"*** the farmers settled on the family farm when a parent took retirement. They aim for production quantity and deliver all of their goat's milk to a dairy. Farms that have expanded since the farmer's installation are relatively large for the sample and in addition to the goat unit, include another activity of beef cattle or sheep of the same importance in terms of income and labour. The interaction between these herds is thought to be the best way to manage the territory of the farm (nearby fields for the goats). The logic of the operation is centred on plant resource management and the assignment of the best feed to the goats. Diversity of surface area (temporary meadows, permanent meadows and cereals) achieves forage self-sufficiency and covers part of the production of concentrates for the animals.

The ***"goat-centred"*** type occurs in smaller farms managed by couples who became established outside the family framework more than 15 years ago because of their passion for the work. The system was built around the goat herd and the processing and marketing of goat's cheese; it has gradually changed, without expanding, to include other activities (educational farm, farm accommodation, bed and breakfast, cottages) and other animal units. It has gradually improved the management of forage resources. In these systems, the diversity of resources, whether animal, vegetable or labour force, is thought to foster system flexibility and efficiency.

The ***"cow-centred"*** type of farming is found in large family-based systems managed by a collective formed progressively by the arrival of new members (family members and employees). The system is designed around the main herd composed of dairy cows, following logic consistent with the dominant model in Livradois-Forez, i.e. intensified production with a forage system based on corn silage and with high use of feed concentrates and chemical fertilizers. The ambition of these farmers is to continue to extend their farms. The goats are secondary, providing added value for the cow's milk via the processing of mixed cheeses. In the 1950s, the majority of farms in the Livradois-Forez had dairy cows and a few goats to make "Brique du Forez", a mixed cheese typical of this territory.

In the last type called ***"limited land area"***, the farmers set up their business outside the family framework, because it was their passion, challenge and desire to change their lifestyle. The project revolves around the processing and marketing of cheeses. The farmers have only recently set up their business; their land area is limited, and their fields do not allow them to produce enough forage to feed their animals, so they resort to purchasing forage and concentrates in varying proportions. They are still

building up systems that have not yet found a balance between livestock production and the management of farm plant resources: at this stage the farmers focus more on the development of cheese processing and marketing.

4.3. …corresponding to different ecological intensification profiles

The analysis of farm ecological intensification profiles shows that there are specificities according to the type of operation (see Figure 2).

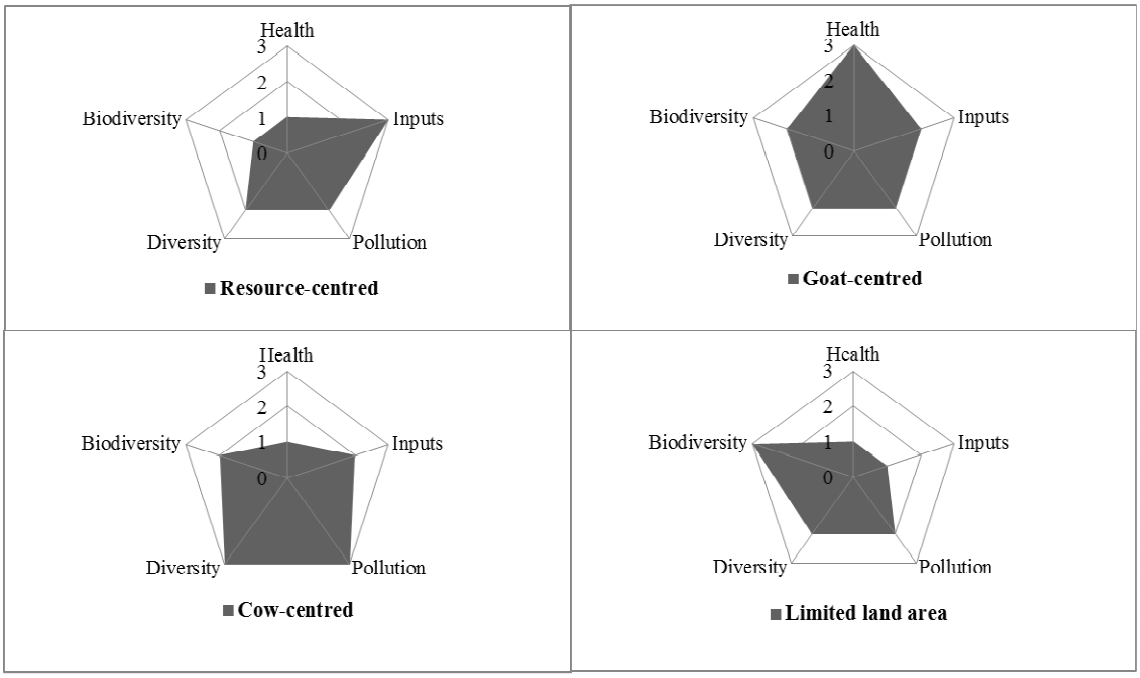

Figure 2. Ecological intensification profile of each operation of goat livestock systems
Degree of ecological intensification depending on number of practices implemented: high = 3 (more than 66%), medium = 2 (between 33 and 66%), low = 1 (less than 33%).

The ecological intensification profile of ***"resource-centred"*** farms is out of balance. It is characterized by the importance of "ecologically-intensive" practices linked to the management of surface areas including those that can reduce inputs (rotations, choice of plant species, grass-legume integration, organic fertilization, organization of fields to reduce movement of stock). On the other hand, animal management favours quantity of milk production over the integrated management of goat health; there is no diet transition, drying-off is sudden, pesticides are used systematically, and animal housing is poorly adapted.

The ***"goat-centred"*** farms are those which have the most balanced ecological intensification profile. Practices that can be described as "dense" from the EI point of

view concern the whole system. Particular attention is given to the integrated management of animal health: the females do not suckle their kids, so as to prevent the transmission from goat to kid of the Caprine Arthritis Encephalitis Virus (CAEV); goats are returned to the building during rainy days to prevent lung problems; feed transitions are reflected, grazing is organized to reduce parasitism, trees in pasture and buildings provide goats with thermal comfort. Farmers have gradually changed their strategy for using animal and plant resources, minimizing inputs and playing on complementarities among animals (remote fields for sheep or horse grazing, whey used for pigs ...).

The ***"cow-centred"*** farms have an EI profile that reflects their ability to promote synergies and recycling via the interaction between plant crops and two different animal herds, dairy cows and goats. The processing of mixed milk cheese enhances the value of the two dairy productions. The possibility of processing cow's cheese when goats are dry also allows the farmers to keep their place on the market all year round. On the other hand, this type of farm is relatively intensive on land use and on animals, with the use of inputs (mineral fertilizers, phytosanitary, and health products).

For the ***"limited land area"*** farms, land management is not or poorly implemented by farmers and food purchases are considerable. The priority of farmers who are starting up their system is to process cheese and develop a marketing network. One hundred percent of the utilized agricultural area is composed of permanent grass grazed or harvested in late mowing to make some hay, but without seeking a high production, which promotes biodiversity (Dumont et al., 2007).

4.3. What promotes or limits the development of goat systems into more ecologically intensive forms

This approach highlighted the links between goat farm operation and EI profile. These links make it possible to identify what promotes or limits the development of these systems into more ecologically-intensive forms.

Thus, the available land area and its features, and the possibility of obtaining more land, condition the possible configurations for interaction between production and resources. Large "resource-centred" family structures where the fields are well grouped together are certainly more likely to develop a strategy of food self-sufficiency than small "Limited land area" structures, whose evolution towards more ecologically-intensive forms depends on their ability to use the land adequately.

Depending on the conditions of his establishment (taking over the family dairy farm after the departure of a parent, installation outside the family framework...) the farmer will not have the same technical livestock farming models as a reference. Goat farming is not dominant in this territory and technical advice on this production does not exist at departmental level. There is no "goat farming model" recognised by the profession or by tradition, with the exception of dairy cows associated with a few goats to process mixed milk cheese, a system that persists in some dairy farms but which remains anecdotal. But even in this latter case, the model that dominates is the dairy cow, with production that is intensive but low according to agroecology principles.

When farmers settled on the family farm, livestock already formed part of one of the two dominant models of the region: dairy cows with a system based on grass, cereals and corn silage, or beef cattle with a grass and crop system. These farms expand and adopt productivity logic. When farmers settle down outside the family, they are looking for a system that allows them to live their profession in accordance with their own values, and they have everything to build. But to do this, they cannot rely on what they learned from their parents. More than others, they have to build their technical knowledge through trial and error, and training and dialogue with other farmers. They will more easily be receptive to forms of livestock farming that do not aim at enlargement and intensification, and which turn to alternative techniques. This is notably the case of farmers of the "goat-centred" category.

The surveys also show that the establishment of an ecologically-intensive farming system takes time. The most favourable EI profile is found in the “goat-centred” system, where farmers who have been established for a long time, tell how they built their system progressively, playing on all the registers (making best use of animal and plant resources, recycling and synergies, diversity and biodiversity). In contrast, the poorly balanced EI profile of the “limited land area" systems can be explained by the lack of time farmers have to implement appropriate practices for the management of resources: they have focused on the processing and marketing of cheese. The system is under construction.

5. Discussion

5.1. A relevant framework…

The application of the approach has enabled us to describe the diversity of goat systems in Livradois-Forez. The absence of a specific goat technical model in this territory partly explains the high diversity of operations observed, within a framework of the livestock exercise: i) combining this activity with other herbivores, ii) managed by a couple or by wider forms of association. The approach showed that each type of livestock system operation was associated with a different ecological intensification profile. It also highlighted the impact of available land, the farm and farmer history, on the livestock system operation and the EI profile. This confirms the need to understand and analyse the farming system, taking into account the trajectory of these systems (Milestad & Darnhofer, 2003 ; Schiere et al., 2012): the systems with the most agro-ecological practices are those developed gradually within the trajectories of couples who were seeking self-sufficiency in food and reduction in inputs rather than the expansion of their farm.

But, this approach does not explain every connection between livestock system operations and ecological intensification profile. Other dimensions are involved in the farmers' reasoning to manage their system: work, economic aspects, wishes and farmers' values.

5.2. …with limits

Our approach to goat systems, their operation and their EI profile is a choice of departure, even though the reality observed emphasizes rare cases of goat specialization. Similarly, the construction of modalities for each variable depends on the diversity of situations and observed practices in the studied area. Our proposed typology has therefore a local and located character, while the proposed approach and framework have the ambition to have a more general scope. Factors identified in this analysis that can discriminate types, such as the size of the goat herds, the product added value (goat's or mixed cheese, market or milk delivery) and the history of the goat unit in the farm, are also candidates for generalization to other samples.

We limited ourselves to a consideration of ecological intensification at farm level when it could be carried out at larger scales. Several authors (Zhang et al., 2007 ; Power, 2010) show that ecosystem services and disservices are often expressed at a

wider scale than the farm. We have not considered the exchange of resources (hay, manure, work) among farmers at local level, and have not identified a form of food self-sufficiency that would favour buying local food (e.g. hay from a neighbour) purchase outside the territory (e.g. Spanish alfalfa, hay from the Crau, soybean meal from Brazil).

5.3. Methodological choices to improve

To build the ecological intensification profile, we have chosen to count the number of management practices associated with each agroecology principle (Altieri, 2002) recalled by Dumont et al. (2013).

In order to assess the performances of the livestock farming systems, Mena et al. (2012) also constructed variables on practices, but based on organic farming specifications and using weighting techniques to construct the variables. In (Guyomard et al., 2013), the performances of the livestock farming systems are also assessed through the link between the practices and 5 "meta-performances": economics, production, use of natural resources, environment and social. In our case, we were not able to rely on a set of specifications as in organic farming, and we did not seek to quantify the influence of each practice on a type of performance.

We sought less to assess the proximity of the EI profile of each system to an ideal profile that would have high modalities for each principle, than to understand how the functioning of a system and the way it was constructed plays on the profile obtained. What is more, assessing performances is difficult and controversial because it often results from a contextualisation of bibliographical knowledge, or from a generalisation of local experiences (Bidaud, 2013).

Other studies have sought to link intensification and ecologisation of practices, based on the reading of a diversity of livestock farming systems (Riedel et al. (2007), Vall et al. (2012) and Ripoll-Bosch et al. (2012), for example). All of these studies mobilised indicators to quantify the intensification and ecologisation of practices, which led the authors to define the perimeter of what constituted ecologically-intensive systems to certain combinations of practices.

We intend to continue this work by refining the inclusion of other management practices in the construction of the EI profile and applying it to other livestock situations.

5.4 Results to be repositioned in the agrifood system

This study is centred on the practices and strategies of livestock farmers. It has to be resituated in the territorial context of the agrifood system to understand how the individual strategies of farmers interact with those of other players (Lamine, 2012). We have mentioned the link between the absence of technical advice and an organised sector in goat farming and the diversity of forms of livestock farming which, in addition, are very largely diversified. In this region there is no official label for goat's cheese. The « Brique du Forez » is a traditional product, but its composition fluctuates depending on the farmer and the season, and it does not in fact benefit from PDO (Protected Designation of Origin) certification. A small dairy in great economic difficulty collects the milk from the "resource-centred" types of farmers to make the Brique du Forez, but the prospects are rather uncertain. Developments in the systems rely hardly at all on collective dynamics or advice specific to the goat sector, but on networks associated with the farm's cattle productions when they exist, or on inter-individual relationships between farmers and consumers or between farmers. Some institutions such as the Chamber of Agriculture and the Parc Livradois-Forez, conscious both of the interest of these farms for the territory and of their isolation, are attempting with difficulty to relaunch collective dynamics.

6. Conclusion

We have shown the usefulness of this approach to understand and analyse the diversity of livestock systems and identify what promotes or limits the development of these systems to more ecologically-intensive forms. In a general context of goat farming combined with other herbivores, the systems are often only partially agro-ecological, if reference is made to practices associated with the five principles of Altieri (2002). The situations in which these principles are followed the most successfully refer back to situations characteristic of small grassland farms, engaged in cheese processing, aiming at self-sufficiency in forage, low-input use, and adaptation to the seasonal nature of goat herd production. These farms also demonstrate that mastery of the balances necessary for this type of system to function in an agro-ecological way, has been built up very progressively over time, confirming the importance of the time factor (Lamine, 2011). We intend to continue this work by refining the inclusion of other management practices in the construction of the EI profile and applying it to other livestock situations.

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V - Revisão de literatura: Inclusão de sais de cálcio de ácidos graxos de óleo de soja nas rações de cabras Saanen lactantes em pastejo

A caprinocultura leiteira tem aumentado sua participação no cenário agropecuário brasileiro. Segundo a Food and Agriculture Organization (FAO, 2012) o Brasil é o maior produtor de leite de cabra da América Latina. Esta produção está concentrada principalmente nos estados nordestinos da Paraíba e do Rio Grande do Norte, onde o leite de cabra tem como destino os programas governamentais de merenda escolar e de combate à desnutrição infantil. Além do nordeste, outras bacias leiteiras estão sedimentadas nas regiões sul e sudeste do Brasil, nestas regiões o leite de cabra é destinado a laticínios para a pasteurização e/ou produção de queijos finos para atender a exigência do mercado consumidor de alta renda, por produtos de qualidade.

Para atender as exigências do mercado por produtos de qualidade e a preços competitivos os produtores precisam definir estratégias que viabilizem a produção e, consequentemente, possam permanecer na atividade. Uma alternativa viável é a utilização de sistemas de produção baseada em pastagens.

1. Produção de leite de cabra em pastagem

As pastagens apresentam grande importância territorial no Brasil, aproximadamente 48% do território nacional é ocupado com pastagens, sendo 122 milhões de hectares de pastagens cultivadas e 52 milhões hectares de pastagens nativas (IBGE, 2010).

No entanto, para que a pastagem torne o sistema produtivo sustentável e econômico é preciso ser manejada racionalmente, considerando aspectos como escolha da espécie cultivada, incremento da fertilidade do solo, taxa de lotação e controle parasitário (Quadros, 2006).

Em sistemas de produção de leite a pasto a escolha da espécie forrageira a ser cultivada deve estar atrelada as exigências nutricionais dos animais, principalmente com relação à quantidade e qualidade da forragem. As gramíneas do gênero *Cynodon*, principalmente *Coastcross* (*Cynodon dactylon*) e Estrela (*Cynodon nlemfuensis*), apresentam grande potencial forrageiro na produção leiteira, principalmente pelas suas características qualitativas e de produção. Os *Cynodons* bem manejados podem chegar a produzir 19 toneladas de matéria seca por hectare ano (Gonçalves et al., 2002; Alvim et al., 2003; Rocha et al., 2006), e de acordo com as Tabelas Brasileiras de Composição de

Alimentos para Bovinos - CQBAL 3.0. (Valadares Filho et al., 2010) a composição dos *Cynodons* variam de 61 a 79% de fibra em detergente neutro, 8 a 17% de proteína bruta, 1 a 3% de extrato etéreo, 6 a 8% de cinzas, e contêm apenas de 9 a 16% de carboidratos não fibrosos (CNF). Estes baixos teores de CNF certamente limitam o uso de boa parte da fração degradável no rúmen da proteína bruta dessa forrageira.

O principal fator limitante à produção de leite em pastagens é a restrição imposta pelo efeito de enchimento ruminal, que resulta em baixa ingestão de matéria seca, consequentemente, de energia. O fornecimento de concentrado é a estratégia mais eficiente para elevar a ingestão de energia de cabras mantidas em pastagem. Para cabras de alto potencial genético mantidas em pastagens tropicais, é preciso fornecer quantidades elevadas de concentrado com alto teor de carboidrato fermentáveis no rúmen.

Diferentes forrageiras são usadas em sistemas de produção de leite de cabra a pasto. Experimento realizado por Macedo et al. (2002) com cabras mestiças Saanen em dois sistemas de produção, a pasto ou semiconfinadas. As cabras no sistema de produção a pasto ficaram todo o tempo em pastagem de estrela africana (*Cynodon nlemfuensis*) e as cabras semiconfinadas, que passavam todo o dia na pastagem de estrela african e durante o período da noite recebiam feno de gramíneas do gênero *Cynodon*; essas cabras foram suplementadas com concentrado para atender 30% ou 60% da exigência em energia liquida, e observaram que o sistema de produção a pasto apresentou o melhor resultado de produção total de leite de cabra.

Min et al. (2005) avaliaram o efeito de três quantidades de suplementação concentrada na produção de leite de cabras Alpinas em pastagem mista (vários tipos de forageiras: trigo (*Triticum aestivum L.),* trevo de Berseem ou trevo de Alexandria (*Trifolium alexandrinum L.*), azevém (*Lolium multiflorum*), capim-sudão (*Sorghum bicolor*), capim-colchão (*Digitaria ciliaris*). As cabras receberam 0,0 kg; 0,33 kg ou 0,66 kg de ração concentrada para cada kg de leite de cabra produzido acima de 1,5 kg/dia observaram o aumento na produção de 1,7 e 0,9 kg para cada kg de concentrado adicionado a dieta durante o primeiro e segundo ano do estudo respectivamente. Min et al. (2005) concluíram também que cabras leiteiras Alpinas em pastejo, sem a suplementação de concentrado pode produzir leite de cabra com baixo custo e, que a resposta à suplementação concentrada é maior em pastagens de baixa qualidade.

Rufino et al. (2012) ao avaliarem o efeito de quatro níveis de suplementação concentrada (0,0; 0,5; 1,0 e 1,5% do peso vivo) de cabras Anglo Nubianas em pastagens

de Tanzânia (*Panicum maximum* Jacq) observaram aumento linear da ingestão da matéria seca e dos nutrientes, na produção de leite de cabra e nos constituintes do leite de cabra.

Ao estudar o efeito de pastagens cultivadas de *Festuca pratensis* e *Phleum pratense* e pastagens naturais em áreas de florestas em comparação a fenos de diferentes qualidades (alta e baixa) na produção e composição do leite de cabras, Steinshamn et al. (2012) observaram que quando manejadas em pastagens cultivadas, as cabras produziram mais leite, e a composição nos teores de gordura e proteína do leite foram aumentados para as cabras mantidas em pastagens com relação as que foram alimentadas com feno.

Assim, de acordo com Macedo et al. (2002), Min et al. (2005), Lefrileux et al. (2008), Rufino et al. (2012) e Steinshamn et al. (2012) a suplementação de cabras em produção mantidas em pastejo tem como objetivo principal aumentar a produção de leite por cabra. No entanto, a produção de leite de cabra a pasto com suplementação concentrada melhora a qualidade do leite, principalmente no que tange o teor de gordura e a composição de ácidos graxos.

Além da importância de se conhecer o desempenho dos animais em sistemas de produção leiteiro em pastagens, a ingestão de matéria seca é outro fator crucial para o entendimento da interação animal-pasto. Contudo, a estimativa da ingestão da pastagem se apresenta como um dos maiores desafios na pesquisa com ruminantes em situação de pastejo, já que as estimativas da ingestão em pastejo ainda continuam sendo deficientes em acurácia e confiabilidade (Carvalho et al., 2007).

No entanto, desde a década de1990, uma variedade de técnicas para a estimativa da ingestão, composição e digestibilidade da dieta de herbívoros foram extensivamente revisadas (Dove e Mayes, 1991, 1996; Mayes e Dove, 2000; Dove e Mayes, 2005). Entre as técnicas, a identificação dos n-alcanos (hidrocarbonetos alifáticos saturados encontrados nas ceras da cutícula das plantas) como indicador para determinar a ingestão, composição e digestibilidade da dieta de animais em pastejo tem se destacado. Dentre os trabalhos publicados para cabras em pastejo, em que foi utilizado os n-alcanos como indicador podendo citar: Decandia et al. (2000); Dove e Mayes (2005); Celaya et al. (2007); Ferreira et al. (2009); Narvaez et al. (2012); Osoro et al. (2013).

O conhecimento do comportamento do animal na pastagem é atualmente compreendido como ferramenta para decisões sobre o manejo de caprinos em pastagens para obter desempenho produtivo satisfatório. Os animais mantidos em pastagens

dividem seu tempo, entre pastejo, deslocamento, ruminação e ócio (Parente et al., 2005; Barros et al., 2008), sendo essas atividades influenciadas por fatores ligados a qualidade e quantidade da pastagem (Bratti et al., 2009; Ferrazza et al., 2012; Ribeiro et al., 2012; Veloso Filho et al., 2013), suplementação concentrada (Silva et al., 2009), categoria animal (Parente et al., 2005), dentre outros fatores.

2. Suplementação lipídica

O Brasil apresenta, praticamente em todo seu território, características de clima tropical, conferindo condições favoráveis para a produção de leite a pasto. Com isso, a pastagem, em regiões de clima tropical, pode ser considerada a principal e mais econômica fonte de nutrientes necessários a manutenção, ao crescimento e a produção para maioria dos ruminantes (Branco et al., 2002). No entanto, em sistemas de produção de cabras com alto potencial genético para a produção de leite esses animais não conseguem obter na pastagem, mesmo que seja de boa qualidade, todos nutrientes necessários para suportar o potencial produtivo que apresentam necessitando assim, de alimentação balanceada.

A inclusão de alimentos concentrados na dieta é uma estratégia para aumentar a densidade energética das rações, e, consequentemente, atender as exigências de cabras com alta produção e/ou para aumentar a produtividade do sistema. Porém, o fornecimento de elevadas quantidades de concentrados contendo altos teores de amido pode acarretar em vários problemas, como redução no teor de gordura do leite, acidose, depressão na digestibilidade da fibra e queda do consumo de matéria seca (Van Soest, 1994). Segundo Lefrileux et al. (2008) cabras que produzem elevada quantidade de leite criadas em pastagem devem receber no máximo 1 kg de concentrado por dia.

Outra estratégia para aumentar a densidade energética das rações e potencializar o desempenho produtivo dos animais lactantes, é a incorporação de alimentos ricos em lipídeos, como o grão e/ou o óleo de oleaginosas (caroço de algodão, soja, girassol, linhaça, etc.) na ração. De acordo com Palmquist (1994) diversos fatores contribuem para essa prática, tais como, a disponibilidade comercial de lipídeos de boa qualidade, o aumento da ingestão de energia quando a de matéria seca é reduzida, a substituição de carboidratos rapidamente fermentáveis por lipídeos possibilita aperfeiçoar o consumo de forragem e a fermentação ruminal, e os lipídeos podem modificar a composição da gordura do leite.

Por outro lado, a fermentação ruminal é frequentemente alterada pela adição de dietas ricas em lipídeos, acima de 5% da matéria seca, não submetidas a tratamentos tecnológicos (Nagaraja et al., 1997). Pois, a digestibilidade da parede celular das plantas pelos micro-organismos é reduzida, e o perfil de ácidos graxos voláteis é orientado para o ácido propiônico (Palmquist and Jenkins, 1980). Os efeitos negativos dos lipídeos sobre a fermentação ruminal são por causa da adsorção dos ácidos graxos às partículas dos alimentos, bem como as bactérias ou, a um efeito tóxico específico sobre as bactérias celulolíticas (Palmquist and Jenkins, 1980). Devendra e Lewis (1974) atribuíram também que a redução da disponibilidade de cátions de cálcio para formação de complexo com ácidos graxos de cadeia longa pode afetar a fermentação ruminal diminuindo a degradação da fibra.

A adsorção dos ácidos graxos às partículas dos alimentos forma um recobrimento físico, principalmente da fibra dos alimentos, dificultando a superfície de contato entre os micro-organismos e as partículas de alimentos (Hobson and Stewart, 1997; Jenkins e McGuire, 2006), com isso prejudica a fixação dos micro-organismos às partículas de alimentos, consequentemente, a fermentação dos carboidratos estruturais pode ser reduzida (Valadares Filho e Pina, 2011).

O efeito tóxico dos ácidos graxos está relacionado aos ácidos graxos poli-insaturados de cadeia longa e aos ácidos graxos de cadeia média, pois esses ácidos graxos são mais solúveis em água e membranas celulares (Palmquist e Mattos, 2011), cujo mecanismo envolve a alteração na permeabilidade da membrana celular, que reduz a capacidade da célula regular o pH intracelular e a captação de nutrientes (Nagaraja et al., 1997). Assim, para diminuir a toxidade dos ácidos graxos os micro-organismos ruminais fazem a biohidrogenação, convertendo ácidos graxos insaturados em ácidos graxos saturados, que são menos tóxicos.

Este efeito negativo dos lipídeos sobre a degradação e digestão dos carboidratos pode ser diminuído quando é feita a suplementação com ácidos graxos saturados ou monosaturados, quando a dieta é rica em cálcio solúvel e/ou feno. Bem como, técnicas de proteção parcial dos lipídeos contra a biohidrogenação ruminal, tais como o encapsulamento dos lipídeos por proteína tratada com formaldeído (McAllan et al., 1983) e a hidrogenação das gorduras e a produção de sais de cálcio (Jenkins e Palmquist, 1982).

Assim, torna-se importante, o desenvolvimento de experimentos envolvendo a suplementação lipídica para caprinos, pois na maioria dos trabalhos com ruminantes são

utilizados bovinos como modelo animal, tornando escassas as informações dos efeitos dos lipídeos na dieta de caprinos. Segundo Van Soest (1994) e Chilliard et al. (2003), os caprinos possuem comportamento alimentar e metabolismo diferenciados em relação a outras espécies de ruminantes, pois são considerados como ruminantes selecionadores intermediários, possuem o hábito do ramoneio e grande mobilidade labial e, portanto, podem apresentar respostas distintas ao fornecimento de lipídeos.

3. Sais de cálcio de ácidos graxos de cadeia longa

Os sais de cálcio de ácidos graxos de cadeia longa são lipídeos insolúveis no rúmen, também conhecidos como "gordura protegida"; sendo inertes no ambiente ruminal. Os sais de cálcio são obtidos a partir da reação de íons de cálcio aos ácidos graxos de cadeia longa formando sabões de cálcio que impedem que ocorra a biohidrogenação dos ácidos graxos insaturados no rúmen. Seu princípio se baseia na passagem deste complexo pelo rúmen e na sua dissociação nas condições ácidas do abomaso, tornando-os disponíveis para digestão e absorção no intestino e liberados na corrente linfática. Atualmente os sais de cálcio comercializados são à base de óleo de palma ou de soja, ricos em ácido palmítico e oleico.

A utilização dos sais de cálcio foi fundada sobre a observação do efeito benéfico do cálcio para evitar perturbações na digestão ruminal, pois o cálcio disponível no rúmen é usado em um processo de saponificação dos ácidos graxos livres no rúmen (Devendra e Lewis, 1974). Sabe-se que os mecanismos de ação do cálcio são complexos, mas o cálcio presente na gordura protegida não altera a fermentação ruminal. No entanto, uma parte dos ácidos graxos dos sais de cálcio podem não escapar da biohidrogenação ruminal, e uma pequena parcela é dissociada no rúmen sem alterar a digestão dos micro-organismos ruminais.

Outro benefício da suplementação com sais de cálcio é o fornecimento de ácidos graxos essenciais aos ruminantes. Segundo o NRC (2007), os pequenos ruminantes não possuem as enzimas Δ12-desaturase e Δ15-desaturase, enzimas necessárias para gerar as duplas ligações n-6 e n-3 necessárias para a biossíntese dos ácidos graxos poli-insaturados linoleicos (grupo dos ácidos graxos n-6) e α-linoleico (grupo dos ácidos graxos n-3). Apesar disso, quando fornecido na dieta esses ácidos graxos sofrem biohidrogenação ruminal, tornando os ácidos graxos poli-insaturados essenciais em ácidos graxos saturados. No entanto, se esses ácidos graxos forem inseridos a dieta na forma de sais de cálcio, que é um produto altamente estável em água e temperatura,

somente é digerido no organismo animal em meio ácido. No rúmen, o meio é apenas ligeiramente ácido (pH 6,2), o que faz com que ele permaneça inalterado. Ao chegar ao abomaso, o meio se torna ácido (pH 2-3) ocorrendo a dissociação dos íons de cálcio com a liberação para o intestino dos ácidos graxos e íons de cálcio, que serão absorvidos e levados pela corrente sanguínea.

Assim, os sais de cálcio são relativamente inertes no rúmen podem ser utilizados para aumentar a densidade nas rações dos ruminantes e consumo de energia sem alterar a atividade microbiana no rúmen (Palmquist and Jenkins, 1980). Isso foi recentemente demostrado pela adição de ácidos graxos na dieta de vacas leiteiras (Côrtes et al., 2010; Crompton et al., 2010; Juchem et al., 2010; Kliem et al., 2011), na dieta de ovelhas (Emediato et al., 2009; El-Shahat, 2010; Obeidat et al., 2012), e na dieta de cabras (Shingfield et al., 2009; Titti, 2011; Baldin et al., 2013; Molina, 2013; Souza et al., 2014b). No entanto, os efeitos na dieta de cabras são contraditórios e precisam ser esclarecidos.

Os efeitos contraditórios dos diferentes estudos publicados sobre a adição de sais de cálcio de ácidos graxos na dieta de cabra podem ser atribuídos aos diferentes níveis de inclusão dos mesmos e de tipos de dietas avaliadas pelos autores (Quadro 1).

Tovar-Luna et al. (2002) estudaram o efeito de quatro níveis de sais de cálcio de ácidos graxos de cadeia longa do óleo de palma (1,2; 2,3 ou 3,5% da dieta; ou seja, 0, 33, 66, ou 99 g/d) na dieta de cabra Alpinas lactantes; estes autores não observaram efeitos para a utilização da gordura inerte no rúmen para o ganho de peso, ingestão dos nutrientes, produção e composição do leite de cabra e concentração da insulina sérica. Os autores apontaram também que pesquisas adicionais são necessárias para determinar o nível de gorduras inertes no rúmen adequada a ser suplementar na dieta de cabras lactantes consumindo diferentes tipos de alimentos concentrados e volumosos.

Lu (1993) observou redução na produção de leite de cabras em lactação suplementadas com 5% de gordura animal na dieta, mas reportaram melhor concentração nos teores de gordura do leite de cabra. Resultados semelhantes foram obtidos por Teh et al. (1994) que ao suplementarem cabras Alpinas em lactação com níveis crescentes de lipídeo inerte no rúmen, 0; 6 ou 9% de sais de cálcio de ácidos graxos de cadeia longa, em dietas iso-proteicas observaram redução na produção, aumento da gordura, e das concentrações de ácidos graxos de cadeia longa do leite.

Quadro 1

Estudos publicados sobre a adição de sais de cálcio de ácidos graxos (SCAG) na dieta de cabras

Inclusão de SCAG			Volumoso	Principais resultados	Estudos publicados
Ingestão	**Níveis**	**Fonte do óleo**			
92 g/dia, 161 g/dia ou 226 g/dia	3%; 6%, ou 9% da dieta		Alfalfa	- Diminuiu a produção de leite - Aumentou a gordura e proteína do leite - Aumentou os ácidos graxos de cadeia longa e de reduziu os ácidos graxos de cadeia curta de leite	Teh et al. (1994)
90 g/dia	9% da ração concentrada	Rico em PUFAs	Feno de alfafa	- Diminuiu a ingestão de material seca - Diminuiu a proteína do leite - Aumentou a gordura do leite - Aumentou os ácidos graxos insaturados do leite	Pérez et al. (2000)
	7% da ração concentrada	Rico em PUFAs	Pastagem	- Aumentou a produção de leite - Aumentou os PUFAs do leite - Diminuiu o ácido esteárico do leite	Sanz Sampelayo et al. (2000)
66.9 g/dia	3% da dieta	Peixe	Feno de alfafa	Não alterou a ingestão, produção e composição do leite	Kitessa et al. (2001)
54,7 ou 60,6 g/dia	9% ou 12% da ração concentrada	Rico em PUFAs	Feno de alfalfa	- Aumentou os PUFAs no leite - Aumentou a utilização da energia metabolizável para a produção de leite	Sanz Sampelayo et al. (2002a) e (Sanz Sampelayo et al., 2002b)
33 g/dia, 66 g/dia, ou 99 g/dia	1,2%; 2,3% ou 3,5% da dieta	Palma	Feno de alfalfa	Não teve efeito na ingestão de matéria seca e na produção e composição do leite de cabra	Tovar-Luna et al. (2002)
75 g/dia	5,4% da dieta	Linhaça	Feno de alfalfa	Altera a fermentação ruminal e a digestão da fibra - Redução do teor de gordura do leite	Cenkvári et al. (2005)
90 g/dia	5% da dieta	Palma	Feno de capim-Tifton 85	- Redução na ingestão de matéria seca e nutrientes	Silva et al. (2007a) e Silva et al. (2007b)
30 g/dia, 60 g/dia ou 90 g/dia	5%, 8% ou 13% da ração concentrada	Girassol	Feno de alfalfa	- Diminuiu a gordura do leite	Shingfield et al. (2009)
45 g/dia e 75 g/dia	3% ou 5% da ração concentrada		Feno de alfalfa	- Aumentou a produção de leite - Aumentou a ingestão de energia metabolizavel	Titti (2011)

Inclusão de SCAG			Volumoso	Principais resultados	Estudos publicados
Ingestão	**Níveis**	**Fonte do óleo**			
41 g/dia; 76 g/dia; 110 g/dia	2,8%; 5,5% e 8,1% da dieta	Soja	Silagem de milho	- Aumentou a ingestão de nutrientes digestíveis totais - Aumentou a gordura e lactose no leite - Diminuiu a proteína do leite -Aumentou os ácidos graxos de cadeia longa e PUFAs do leite	Souza et al. (2014b) e Souza et al. (2014a)
13 g/dia; 27 g/dia; 38 g/dia ou 50 g/dia	0,6%; 1,3%; 1,9% ou 2,5% da deita	Soja	Feno de aveia	- Diminuiu a proteína do leite - Aumentou o ácido linolênico no leite	Molina (2013)

De acordo com os resultados obtidos por Pérez et al. (2000), Sanz Sampelayo et al. (2000), Kitessa et al. (2001) e Sanz Sampelayo et al. (2002a), que ao suplementarem cabras, no meio da lactação, com diferentes níveis sais de cálcio de ácidos graxos (variando entre 3% e 12% do concentrado), a ingestão de matéria seca e a produção de leite não sofreram efeitos. Ao contrário, quando o mesmo suplemento foi adicionado na dieta de cabras no final de lactação houve aumento na produção de leite e nos teores de gordura e proteína do leite de cabra (Sanz Sampelayo et al., 2004).

Silva et al. (2007a) concluíram que os sais de cálcio de ácidos graxos do óleo de palama são bons substitutos aos carboidratos fermentáveis para cabras quando o objetivo é elevar a concentração energética das dietas de cabras em lactação. No entanto, observaram que os sais de cálcio de ácidos graxos de cadeia longa reduziram a produção do leite.

Porém, para Titti (2011) a adição de sais de cálcio (0 %, 3% ou 5 % da dieta total; 0; 45; ou 75 g/dia) em cabras Shami na fase inicial da lactação aumentou a produção de leite. Segundo Souza (2012) a suplementação com sais de cálcio do óleo de soja na dieta de cabras Saanen em lactação aumentou a produção de leite. O autor também observou aumento nos teores de ácidos graxos de cadeia longa (AGCL) no leite, diminuindo a síntese de ácidos graxos de cadeia média (AGCM) e curta (AGCC). A suplementação com sais de cálcio na dieta de cabras em lactação possibilitou também aumentar a proporção dos ácidos graxos essenciais ômega-3 (n3) e ômega-6 (n6). Assim, a gordura protegida nas rações age sobre a composição da gordura do leite, aumentando a quantidade de ácidos esteárico e oleico e, diminuindo de ácidos graxos de cadeia curta e do ácido palmítico (Schmidely e Sauvant, 2001).

Em avaliação com 15 cabras Saanen suplementadas com 75 g/dia sais de cálcio do óleo de linhaça (5,4% da dieta total) Cenkvári et al. (2005), observaram que a composição do leite foi alterada, com redução dos teores de gordura e sólidos totais. Shingfield et al. (2009) também observaram redução no teor de gordura do leite de cabras suplementadas com 5; 8 ou 13% de sais de cálcio do óleo de girassol na ração (30, 60 ou 90 g/dia), e atribuiu esse efeito a redução na secreção de ácidos graxos pela síntese *de novo* em virtude do efeito antilipogênicos do ácido graxo trans-10, cis-12 CLA presente nos sais de cálcio.

A adição de gordura em dietas de ruminantes é feita primariamente para aumentar o nível energético da dieta. Contudo, outro benefício da utilização de sais de cálcio na dieta de ruminantes é que esses animais transferem os ácidos graxos da dieta diretamente para o leite.

Existe uma associação entre a suplementação de gordura e a redução na concentração de proteína do leite de ruminantes. Desde que a densidade energética da dieta seja normalmente aumentada com a suplementação de gordura, o teor de proteína da dieta precisa ser elevado para assegurar que não haja depressão da proteína do leite (Holter et al., 1993). O que é explicado pela diminuição de energia disponível aos micro-organismos no rúmen, quando suplementados com sais de cálcio de ácidos graxos de cadeia longa, diminuindo a eficiência de utilização do nitrogênio para síntese de proteína microbiana e aporte de aminoácidos para os animais.

Wu e Huber (1994) afirmaram que a principal causa para a redução do teor de proteína do leite está relacionada à deficiência no aporte de aminoácidos que chegam à glândula mamária para síntese de proteína do leite. Estudos recentes relataram depressão dos teores de proteína do leite de cabras suplementadas com sais de cálcio de ácidos graxos de cadeia longa do óleo de soja, rico em ácidos graxos insaturados (Souza, 2012; Molina, 2013). Para Morand-Fehr (2005) em caprinos uma fonte de lipídeos em proporções adequadas, não muito rica em ácidos graxos insaturados e em menos de 5% da MS da dieta, geralmente não reduz a porcentagem de proteína do leite ou o índice de rendimento de queijo.

Silva et al. (2007b) ao avaliarem o efeito da inclusão de três fontes de lipídeos na dieta: óleo de soja, sais de cálcio de ácidos graxos de cadeia longa ou grão de soja, na dieta de cabras, observaram que 90 g/dia (5% da dieta total) de sais de cálcio não influenciaram o pH ruminal e, a síntese e a eficiência de proteína microbiana, mas reduziram a concentração de amônia no rúmen. Esses autores concluíram que a inclusão

de 5% na dieta total de sais de cálcio (dieta com 6,5% de extrato étérero) pode ser utilizada de modo eficiente em dietas para caprinos.

Em revisão de literatura, Sanz Sampelayo et al. (2007) analisaram resultados experimentais para identificar o efeito de diferentes tipos de suplementação lipídica no leite de cabras, mostraram que a suplementação lipídica não altera a ingestão de energia líquida e produção de leite. Mas proporciona aumento, na maioria dos casos, do conteúdo de gordura do leite e das concentrações de ácidos graxos poli-insaturados, como os ácidos graxos oleico, vacênico, rumênico e linoleico, e diminuição dos ácidos graxos de cadeia curta.

Um adequado balanço nutricional é necessário para o animal expressar seu máximo desempenho produtivo; e através da análise do perfil metabólico dos animais é possível diagnosticar alterações no balanço energético, proteico e mineral. Assim a glicose, o colesterol e os triglicerídeos estão associados ao metabolismo energético; sendo a síntese do colesterol e dos triglicerídeos aumentada em casos de excesso de energia alimentar e na carência de glicose sanguínea. A ureia plasmática está associada com a integração do metabolismo energético e da degradação de compostos nitrogenados. E o cálcio e o fósforo representam os minerais. Segundo (Mundim et al., 2007) a glicose, triglicerídeos e cálcio total, são biomarcadores plasmáticos eficazes para diagnosticar alterações no balanço energético e mineral em cabras lactantes.

Os ácidos graxos estão presentes no sangue na forma de triglicerídeos, fosfolípides e ésteres de colesterol. Para bovinos leiteiros o aumento da concentração dos ácidos graxos no sangue ocorre quando aumenta a suplementação com lipídeos. No estudo de Rapetti et al. (2009); os sais de cálcio do óleo de palma alteraram as concentrações de colesterol e triglicerídeos no sangue de cabras. Enquanto, Souza et al. (2014a) e Molina (2013) observaram efeito apenas para o colesterol plasmático com a inclusão de sais de cálcio. No entanto, em outros estudos não foram observadas diferenças para os metabolitos sanguíneos, colesterol e triglicerídeos, quando adicionado sais de cálcio na dieta de cabras no inicio da lactação (Bernard et al., 2005; Titti, 2011).

A glicose está entre os metabólitos sanguíneos mais usados para avaliar o *status* energético; e a ureia sanguínea é empregada como indicador do metabolismo proteico do animal em curto prazo. Molina (2013) avaliou o efeito da inclusão de sais de cálcio de cadeia longa na dieta de cabras em lactação e observou que não houve diferença, para o nível de glicose e ureia.

Com base nas respostas obtidas pelos estudos publicados até o momento sobre a suplementação de cabras com sais de cálcio de ácidos graxos de cadeia longa, conclui-se que os sais de cálcio de ácidos graxos insaturados de cadeia longa é um alimento empregado para a suplementação de cabras em lactação. No entanto, vendo as diferenças nas respostas produtivas obtidas, novas pesquisas precisam ser feitas para elucidar esses resultados.

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VI - Effect of calcium salts of fatty acids on nutritive value of diets for lactating Saanen goats grazing Stargrass (*Cynodon nlemfuensis*)

(Normas: Small Ruminant Research)

Abstract

This objective of this study was to determine effects of the addition of calcium salts of fatty acids (CSFA) to concentrate on the intake and digestibility of dry matter and nutrients and the grazing behavior of lactating Saanen goats. Five multiparous Saanen goats (five years old) in their third lactation and four primiparous Saanen goats (three years old) were used. The animals were distributed into two Latin square designs, which for the multiparous goats was 5x5 with five treatments (0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA) and for the primiparous goats was 4x4 with four treatments (0%, 1.5%, 3.0% and 4.5% CSFA). Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and CSFA derived from soybean oil at the set levels of inclusion. For grazing goats, an area with Stargrass (*Cynodon nlemfuensis*) was used. The grazing behavior of goats was assessed by registering the time spent grazing, ruminating standing or lying, an resting standing or lying. Goat dry matter intake and digestibility were estimated by the n-alkane concentration in forage and feces, including those naturally present in the diet (C_{31} and C_{33}) and the orally administered homologue C_{32}. The addition of CSFA to the concentrate of lactating Saanen goats did not influence the time spent grazing, ruminating or lying for multiparous goats. However, for primiparous goats, for the time spent grazing, there was negative quadratic effect, with the addition of CSFA to the concentrate. The treatments did not affect the intake of dry matter, organic matter, crude protein, neutral detergent fiber, total carbohydrates, non-fiber carbohydrates or total digestible nutrient for multiparous goats. No effects were observed on nutrient digestibility, except for crude protein and the ether extract, which increased the energy values of the diets with 3.5% CSFA. For primiparous goats, no effects were observed on intake or digestibility. In conclusion, the addition of CSFA can be used as an alternative to feed primiparous goats in grassland when the grazing time is a factor limiting intake. The addition of up to 3.5% CSFA enhances the energy value of diets for multiparous goats.

Key-words: dairy goats, grazing behaviour, n-alkanes, rumen-inert fat, soybean oil, tropical climate

1. Introduction

Grassland livestock systems are an alternative to produce quality products at competitive prices. These systems can improve production indices while considering the economic, social and environmental sustainability of the production process.

However, milk production in grassland systems is limited by rumen filling, resulting in low dry matter intake, and consequently low energy intake. Thus, according to Rufino et al. (2012) and Steinshamn et al. (2012), supplying lactating goats in grassland systems with concentrate should be done to increase the milk yield. Feeding with concentrate is a strategy to increase the energy intake of grazing goats. For dairy goats with genetic potential grazing on tropical forages, a high quantity of concentrate is needed to provide the goats with ruminally fermentable carbohydrates. However, the high starch content may result in several problems such as reduced milk fat, metabolic acidosis, decreased fiber digestibility and reduced dry matter intake (Van Soest, 1994).

Other strategies to increase the concentrate energy content are used to improve the performance of lactating animals, such as adding to the diet foods that are rich in lipids, i.e. oilseed grain and/or oil (cottonseed, soybean, sunflower, linseed, etc.). According to Palmquist (1994), several factors affect this management practice, such as the commercial availability of high quality lipids, increased energy intake when dry matter intake is reduced, the replacement of carbohydrates with lipids which improves grass intake and ruminal fermentation, and the fact that lipids can change the milk yield and composition.

In general, adding lipids to the diet of lactating animals is an alternative to increase the diet energy density and improve nutrient digestibility. In addition, lipids improve fat-soluble vitamin absorption, supply fatty acids to the membranes of tissues, act as precursors of metabolic pathways and increase certain fatty acids in milk fat, especially polyunsaturated fatty acids (Palmquist and Mattos, 2011). However, depending on the amount supplied, the degree of unsaturation and the degree of rumen-protected lipids, reduced performance can occur owing to the decreased activity of cellulolytic microorganisms, and the consequent reduction in fiber digestibly (Palmquist and Mattos, 2011).

The addition of rumen-inert lipid in the form of calcium salts of fatty acids (CSFA) were proposed by Jenkins and Palmquist (1982). CSFA is a complex of calcium ions with long chain fatty acids, the main sources of which are soybean oil or palm oil, depending on the commercial product. CSFA is inert in the rumen and is

dissociated in the acidic conditions of the abomasum. Among the benefits of CSFA are the possibility of increasing the energy content of the diet without influencing fiber digestibility, thereby allowing high levels of inclusion in ruminant diets. In this sense, CSFA is interesting, because it does not change ruminal fermentation (Sirohi et al., 2010) and also improves milk quality (Souza et al., 2014). Thus, CSFA is an energy supplement, which in combination with other foods, can increase the dry matter intake, therefore providing good availability of nutrients for satisfactory responses in females for milk production.

Goats with high yield need more nutrients, mainly energy, to support their high levels of productivity. When reared in a grassland, goats can reduce the time spent grazing and, consequently, dry matter and energy intake to maintain productivity. According to Ferrazza et al. (2012), Ribeiro et al. (2012) and Veloso Filho et al. (2013), the time spent to grazing, ruminating and resting normally change according to the quality and quantity of forage. Furthermore, according to Silva et al. (2009), supplementation with concentrate can also change grazing behavior. Van Soest (1994) reported that the time spent ruminating is directly linked to neutral detergent fiber and the physical form of the diet. Thus, monitoring and understanding ruminant grazing behavior are essential to the efficient management of livestock systems.

A suitable nutritional intake is needed for maximum productive performance, and through the analysis of the blood biochemical profile, it is possible identify changes in energy, protein and mineral balance. Therefore, glucose, cholesterol and triglycerides are related to energy metabolism, and the synthesis of cholesterol and triglycerides increase when there is excess food energy and deficient blood glucose. Plasma urea is linked to energy metabolism and the degradation of nitrogenous compounds. According to Mundim et al. (2007), glucose, triglycerides and calcium are the plasma biomarkers best used to assess changes in energy and mineral balance in milking goats.

Therefore, this study aimed to evaluate the effect of CSFA in the concentrate fed to multiparous and primiparous lactating Saanen goats on grazing behavior, the nutritive value of the diet and serum blood metabolites.

2. Material and methods

2.1 Goats and experimental treatments

The experiment was conducted at an experimental farm at the State University of Maringá, southern Brazil, in the northwestern region of Paraná State, city of Maringá 23°S latitude and 52°20' W longitude, with an altitude of 550 meters. The climate, according to the classification of Köeppen (Caviglione et al., 2000) , is characterized as mesothermal Cfa - Humid Subtropical. The average monthly values of the meteorological data collected during the experimental period are shown in Table 1.

Five multiparous Saanen goats (five years old) on their third lactation (body weight 57 kg ± 2.7) and four primiparous Saanen goats (three years old; body weight 54 kg ± 1.8) were used. The goats had an average of 78 ± 10 days in lactation at the beginning of the experiment and an average milk yield of 2.8 $kg.day^{-1}$ ± 0.1 and 2.7 $kg.day^{-1}$ ± 0.1 for multiparous and primiparous goats, respectively. Goats were distributed into two Latin square designs with an experimental period of 21 days, including 14 days for adaptation and seven days for data collection. The Latin square design was 5x5 with five treatments (0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA) and for the multiparous goats and a 4x4 Latin square design with four treatments primiparous goats (0%, 1.5%, 3.0% and 4.5% CSFA).

Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and rumen-inert fat in the form of CSFA from a commercially available product derived from soybean oil (Lactoplus® from Dalquim Chemical Industry Ltd.; with 1.94 $g.g^{-1}$ total digestible nutrients, 820 $g.kg^{-1}$ ether extract, 100 $g.kg^{-1}$ calcium, 260 $g.kg^{-1}$ oleic acid and 420 $g.kg^{-1}$ linoleic acid) at the set levels of inclusion (0%, 1.5%, 3.0%, 4.5% and 6.0% of the concentrate) (Table 2). The among of concentrate offered to the goats was established at 1 $kg.day^{-1}$ as feed, representing half of the estimated nutritional requirements of Saanen goats (NRC, 2007) with and average body weight of 60 kg and a milk yield of 3.0 $kg.day^{-1}$ with 3.5% fat.

Goats were milked manually twice daily (7:30 am and 3:30 pm). The goats remained in the grassland for approximately seven hours (8:00 am to 3:30 pm). After the afternoon milking, goats were fed with the concentrate and were housed in individual pens for the evening and overnight. The goats had free access to water in the grassland and pens.

From day 10 to 19, a cellulose capsule of synthetic paired chain *n*-alkane ($C_{32}H_{66}$, Dotriacontane, 97% purity, ref. no. D223107, Sigma-Aldrich Corp., St Louis, MO, USA) was inserted into the rumen by an oral probe twice daily at 08:00 am and 4:00 pm, supplying a total of 80 mg of $C_{32}H_{66}$/day.

For grazing goats, an area of one hectare (1 ha) was used with Stargrass (*Cynodon nlemfuensis*) maintained by continuous stocking (Table 3). The grassland was fertilized and corrected through physical and chemical analysis of the soil and grass demand. Fertilizer was applied at an N-P-K ratio of 8 $kg.ha^{-1}$ nitrogen, 67 $kg.ha^{-1}$ phosphorus and 70 $kg.ha^{-1}$ potassium (200 kg of N-P-K fertilizer 4-20-20, 150 kg of single superphosphate and 50 kg of potassium chloride) in September 2011, which was distributed by throwing 30 days before the input of goats. The grazing period was from October 8 2011 to January 20 2012.

2.2 Samples collection and analyses

Samples of the forage for chemical analysis and manual separation of the morphological components (leaf blades, stems and sheaths, dead material) were collected once in each experimental period; to ensure random sampling, one 1.0 m² wire square was thrown eight times in the paddock and the grass was cut 15 cm above the ground. Samples of forage to determine total forage mass were cut close to the soil. The sward height was measured with a wooden ruler graduated in centimeters at 20 random points. For the chemical analysis, samples of concentrate were taken during each experimental period and pooled.

Fecal grab samples were taken twice daily at 8:00 am and 4:00 pm from day 15 to 20 and a portion (about 30 g) was dried for 48 h at 55°C and composited by goat within period for later chemical analysis.

Samples of forage and feces from each period were oven-dried (55°C for 72 h), then ground through a 1-mm screen in a Wiley mill. The concentrate was ground through a 1-mm screen in a hammer mill. Dry matter was determined according to AOAC method no. 934.01 (1998). Ash was determined by combustion in a muffle furnace according to method no. 942.05 (AOAC, 1998). Calcium and phosphorus were analyzed using acid digestion with nitric and perchloric acid (1:2). After that, they were filtered to obtain a mineral solution. Calcium and phosphorus readings were obtained using atomic absorption (GBC 932 AA spectrophotometer in an air-acetylene flame) and colorimetry (Shimadzu UV-1601 UV-Visible spectrophotometer) (AOAC, 1990).

Total nitrogen (TN) was evaluated using a Tecnal TE-036/1 apparatus (Tecnal, Piracicaba, São Paulo, Brazil) following AOAC method no. 988.05 of (1998) and crude protein (CP) was estimated as TN x 6.25. The ether extract (EE) was assessed using a Tecnal TE-044/1 apparatus according to method no. 920.39 (AOAC, 1998). The neutral detergent fiber (NDF) was evaluated as described by Van Soest et al. (1991) without the use of sodium sulfite and with the inclusion of heat-stable α-amylase (alpha-amylase Termamyl 2x, Tecnoglobo®, Curitiba, Brazil). Total carbohydrates (TC) and total digestible nutrient (TDN) were estimated according to equations described by Sniffen et al. (1992): TC ($g.kg^{-1}$ of DM) = 1000 - (CP + EE + ash) and TDN = dCP + (2.25 × dEE) + dTC, in which dCP = digestible crude protein, dEE = digestible ether extract, and dTC = digestible total carbohydrates. The method used to calculate feed energy values ($Mcal.kg^{-1}$) using digestible energy (DE), metabolizable energy (ME) and net energy for lactation (NE_L) were done using the following equations (NRC, 2007): DE = 0.04409 × TDN(%); ME = 1.01 × DE - 0.45; and NE_L = 0.0245 × TDN(%) - 0.12. Gross energy content was determined by combustion in a adiabatic bomb calorimeter (Parr Instrument Co.AC720®, Parr Instrument Company, USA).

The *in vitro* dry matter and organic matter digestibility (*IV*DMD and *IV*OMD, respectively) of the five concentrates and Stargrass were determined according to the procedure described by Tilley and Terry (1963) using an artificial rumen (ANKOM Technology®, Macedon, New York, USA) according to Santos et al. (2000). The rumen fluid used as an inoculum was drawn from the rumen of the three cannulated Saanen-Boer goats, fed with Stargrass, and transferred into pre-warmed thermos bottles. The *in vitro* digestibility (*IV*D) was calculated as the difference between the incubated and residual amount of feed using the following equation: *IV*D =100 – [(W3 – (W1 × W4)) × 100/W2], where W1 is the empty filter weight, W2 is the sample weight, W3 is the filter final weight and W4 is the filter blank correction.

The measuring of grazing behavior of lactating Saanen goats was by observing each goat with identification from the 16^{th} to 18^{th} day of each experimental period. The goats were assessed by direct observation three days per period, during the grazing period (six hours per day), with observations every 10 minutes (Carvalho et al., 2007), totaling 108 observation per goat per period, consequently totaling 2700 observations for multiparous goats and 1728 observations for primiparous goats. The goat's activities were assessed by the registry according to the time spent grazing, ruminating standing and lying, and resting standing and lying. The behavioral activities were considered

mutually exclusionary, in other words, for every registry, each animal was classified in only one activity.

On the days used for measuring the grazing behavior of lactating Saanen goats, environmental variables were recorded, including wind speed, air temperature, air relative humidity and dew point temperature, were collected using a hygro-thermo-anemometer (Kestrel 3000®). The black-globe temperature was obtained by a black plastic ball with a 15 cm diameter and an alcohol column thermometer (black-globe thermometer). During data collection, the equipment was positioned 0.8 m above the soil, simulating the height at the goat dorsum. The climate data collection was performed simultaneously with measuring ingestive behavior, every hour during the six hours of grazing.

For the evaluation of the environment, the black-globe temperature and the humidity index (TBHI) were used, as proposed by Buffington et al. (1981), and used to determine the radiant thermal load (CTR), as proposed by Esmay (1969) using the following equations: $TBHI = T_{BG} + 0.36\ T_{DP} + 41.5$; $CTR\ (W.m^{-2}) = \sigma\ T_{RM}^{4}$ and $T_{RM} = 100\ (2.51\ W_S\ 0.5\ (T_{BG} - T_A) + ((T_{BG} + 273.15) / 100)^4)^{0.25}$; in which T_{BG} is the black-globe temperature (°C), T_{DP} is the dew point temperature (°C), σ = Stefan-Boltzmann constant ($5.67 \times 10^{-8}\ W.m^{-2}.K^{-4}$), T_{RM} = average radiant temperature (ºK), T_A = air temperature (ºC) and W_S= wind speed ($m.s^{-1}$).

To determine the serum blood biochemical composition, i.e. glucose cholesterol, triglycerides, urea, calcium, phosphorus, blood sampling was performed after the morning milking, every 17th day of each experimental period. Blood samples were collected by puncture of the jugular vein, using disposable hypodermic needles, and the blood was placed in test tubes containing 10 mL. After 15 minutes at 3,400 rpm at room temperature in a centrifuge (Tecnal 2006-BABY I®), serum was obtained from the blood, which was placed in Eppendorf tubes and frozen for subsequent analyses.

Glucose, cholesterol, triglycerides, urea, calcium and phosphorus serum blood concentrations were analyzed using commercial kits (glucose-PP CAT. 434, cholesterol-PP CAT. 460, triglycerides-PP CAT. 459, urea-PP CAT. 427, calcium-PP CAT 448, phosphorus-PP CAT 342; Gold Analisa Diagnostica®) in a spectrophotometer (Shimadzu UV-1601 UV-Visible Spectrophotometer®).

2.3 Extraction, identification and quantification of n-alkanes

The extraction and determination of the *n*-alkane content in forage and feces were performed according to Mayes et al. (1986), modified by Vulich et al. (1995); the analysis was based on direct saponification of samples.

A gas chromatograph (GC Agilent 7890A®) equipped with a mass selective detector (MS Agilent 5975C®) was used to identify and quantify the *n*-alkanes. The column used was a Zebron™ ZB-5MS (30 m x 0.32 mm x 0.25 µm, absorbent composed of 5% phenyl-arylene-95% polydimethylsiloxane). The carrier gas was H_2 at a constant flux of 1 mL/min. Temperature gradients were controlled for the injector (300ºC) and the column (130ºC for 1 min; 10ºC/min until 210ºC, and 5ºC/min to 310ºC hold for 1 min; 32 min). The MS source temperature was set at 250ºC and the temperature of the MS quadrupole was 120°C. With a microliter syringe, 1 µL of the sample was injected with a split ratio of 1:10.

The gas chromatograph process was calibrated with an external standard solution of a synthetic *n*-alkanes mix C_{24}, C_{26}, C_{28}, C_{32}, C_{34} and C_{36} (Tetracosane 99% purity ref. no. T8752, Hexacosane 99% purity ref no. 241687, Dotriacontane 97% purity ref. no. D223107, Tetratriacontane 98% purity ref. no. 287261, Hexatriacontane 98% purity ref. no. 52919; Sigma-Aldrich Corp., St Louis, MO, USA). The chromatography peak areas corresponding to each *n*-alkane were determined by MSD ChemStation Data Analysis®. The identified peaks were converted to *n*-alkane quantity with regard to each peak area and the internal standard C_{34}, then calculated as $mg.g^{-1}$ of DM.

The dry matter intake (DMI) was estimated in forage and feces based on the concentration of *n*-alkanes naturally present in the diet (C_{31} and C_{33}) and the homologue C_{32}, which was orally administered. The estimated values of DMI with the pairs C_{31}:C_{32} and C_{33}:C_{32} were obtained by the equation of Mayes et al. (1986): $DMI=[(F_i/F_p)*D_p]/[H_i-(Fi/F_p)*H_p]*100$; where: DMI= dry matter intake ($kg\ MS.day^{-1}$); F_i = *n*-alkane of unpaired chain (C_{31} or C_{33}) content ($mg.kg^{-1}$ MS) in feces; F_p = *n*-alkane of paired chain (C_{32}) content in feces; D_p = quantity (mg) of synthetic *n*-alkane of paired chain (C_{32}) fed; H_i = natural n-alkane of unpaired chain (C_{31} or C_{33}) content in forage , H_p = natural *n*-alkane of paired chain (C_{32}) in forage. The DM digestibility was estimated by the equation: DMD = 1-(ID/IF) x 100; where: DMD= dry matter digestibility coefficient by n-alkane, ID = internal content of n-alkane in forage, and IF = internal content of n-alkane in feces.

2.4. Statistical Analysis

The data were assessed by variance analysis, curve estimation linear and quadratic regression equations ($\alpha = 0.05$), with the general model: $Y_{ijkl} = \mu + T_i + P_j + A_l + e_{ij}$ where: Y_{ijkl} = the dependent variable, μ = general constant; D_i = effect of concentrate *i*; P_j= effect of period *j*; Al = effect of animal *l*; e_{ijkl} = random error.

3. Results

The average values of the environmental variables, including air temperature, black-globe temperature, air relative humidity, wind speed, temperature of black-globe and humidity index and radiant thermal load in each experimental period are shown in Table 4.

The addition of calcium salts of fatty acids (CSFA) to the concentrate fed to lactating Saanen goats did not influence the time spent grazing, ruminating and lying for multiparous goats (Table 5). However, for primiparous goats, there was negative quadratic effect for the time spent grazing with the addition of CSFA to the concentrate.

There was no significant effect on the intake of dry matter, organic matter, crude protein, neutral detergent fiber, total carbohydrates, non-fiber carbohydrates or total digestible nutrients for multiparous grassland Saanen goats fed with the concentrates containing CSFA (Table 6). However, the ether extract intake increased linearly with the addition of CSFA to the concentrate. The digestibility coefficients of dry matter, organic matter, neutral detergent fiber, total carbohydrates and non-fiber carbohydrates were not changed by CSFA in the concentrates. However, a significant effect of crude protein and ether extract digestibility coefficients led to an increase in the energy value of the diet, total digestible nutrients, digestible energy, metabolizable energy and net energy for lactation.

When primiparous lactating Saanen goats were fed CSFA, there was no significant effect on the intake and digestibility coefficients of dry matter and nutrients; consequently, the energy value of diets was not changed. However, the inclusion of CSFA changed the ether extract intake and digestibility coefficients (Table 7).

The treatments did not affect the serum blood concentration of glucose, cholesterol, triglycerides, urea, calcium and phosphorus in Saanen goats, either multiparous or primiparous. However, there was a liner increase in the cholesterol concentration when multiparous goats were fed CSFA (Table 8).

4. Discussion

The air temperature during the grazing period was within the comfort zone for goats, i.e. 20 to 30ºC (Baêta and Souza, 2010), except for two experimental periods (periods 3 and 5) where the maximum environmental temperature exceeded 30ºC. However, in this study, the air temperature did not exceed the superior critical temperature for goats (35ºC).

The air relative humidity ranged from 34 to 81%. According to Baêta and Souza (2010), the ideal relative humidity for animal rearing is between 50 to 70%, thus the animals spent the most part of the grazing period in ideal humidity conditions.

To assess the suitability of a facility's thermal comfort, several indices are used. The temperature of the black globe and the humidity index (TBHI) proposed by Buffington et al. (1981) is a more exact indicator of animal comfort, principally when animals are exposed to direct and indirect solar radiation. The averages of TBHI were above those of normal conditions (average = 87.16; minimum = 78.1 and maximum = 93.3) according to Baêta and Souza (1997) (TBHI values up to 74 define a comfortable situation; 74 to 78 an alert situation; 79 to 84 a dangerous situation, and over 84 an emergency).

Although, the environmental conditions were not favorable for livestock grazing, the goats yielded close to the expected 3 $kg.day^{-1}$; i.e. the milk yields for multiparous and primiparous goats were 2.8 and 2.7 $kg.day^{-1}$, respectively. This yield was achieved by the goats because, in addition to forage, the goats were fed with 1 $kg.day^{-1}$ of concentrate, thus it was possible achieve the nutritional requirements and maintain the yield.

The addition of CSFA to concentrate did not influence the time spent grazing, ruminating and resting in multiparous goats. However, the addition of CSFA to the concentrate for primiparous goats changed the time spent grazing; the critical level, in other words the shortest time spent grazing, was reached when the addition of CSFA was 2.5%. Although the treatment decreased the time spent grazing, there was no effect on dry matter intake or milk yield in primiparous goats. This result is interesting when the time for grazing is a limiting factor for dry matter intake.

Factors other than supplementation with concentrated feed can influence intake behavior. Bratti et al. (2009) concluded that the structural characteristics, such as the mass of leaf blades and stems with sheaths, are a fundamental factor in animal grazing preference. Carvalho et al. (2006) evaluated different fiber levels in terms of the neutral

detergent fiber in the forage and diet on the intake behavior of goats in lactation, and concluded that with feeding, ruminating and total chewing time linearly increased with an increase in the neutral detergent fiber level in the diet. However, in this study, the grass structural characteristics did not change among the treatments, and the small amount of CSFA added to the concentrate did not influence grass intake behavior.

The time spent in feed intake was intercalated with one or more ruminating and resting periods. Therefore, multiparous goats dedicated 72% of their time in grazing, 17% in ruminating and 11% in resting. On the other hand, primiparous goats dedicated 78% of their time in grazing, 16.5% in ruminating and 5.5% in resting. The greater amount of time dedicated to grazing and the lesser amount of time dedicated to resting by primiparous goats may be related to the higher nutritional requirements of these animals, which besides maintenance and production requirements, require nutrients for growth. Therefore, these animals supposedly increased their grazing and ruminating time to optimize the dry matter intake. However, the milk yields for multiparous and primiparous were similar, i.e. 2.8 and 2.7 $kg.day^{-1}$, respectively.

The dry matter and nutrient intake was not modified by the addition of CSFA to the concentrates of multiparous or primiparous Saanen goats on a Stargrass grassland, which were 2.0 and 2.1 $kg.day^{-1}$ of DMI, respectively. Molina (2013) also showed 2.0 $kg.day^{-1}$ of DMI for Saanen goats fed with 0, 6.25, 12.50, 18.75 and 25.0 $g.kg^{-1}$ of CSFA from soybean oil in the diet. When compared to other studies in which the goats were kept on a grassland, these results are in agreement. Rufino et al. (2012) supplemented Anglo-Nubian goats with 1.5% of body weight on Tanzania-grass and showed 1.89 $kg.day^{-1}$ of DMI. Mancilla-Leytón et al. (2013) observed 1.87 $kg.day^{-1}$ of DMI when goats were supplemented with 0.5 $kg.day^{-1}$ of concentrate in scrublands (158.8 $g.kg^{-1}$ CP and 579.4 $g.kg^{-1}$ NDF).

According to the NRC (2007), for grazing multiparous goats with 57 kg of body weight and 3.0 $kg.day^{-1}$ of milk yield, the metabolizable energy (ME) requirement for maintenance, production and activity is 4.65 $Mcal.day^{-1}$. Grazing primiparous goats with 54 kg of body weight and 2.7 $kg.day^{-1}$ of milk yield require 4.25 $Mcal.day^{-1}$ of ME. The multiparous and primiparous goats in this study ingested 2.04 and 2.11 $kg.day^{-1}$ of DM, and the averages values of ME in the diets were 2.53 and 2.54 $Mcal.kg^{-1}$, respectively. Thus, all energy requirements for maintenance, production and activity were supplied (5.16 and 5.36 $Mcal.day^{-1}$ of ME intake for multiparous and primiparous goats, respectively) and the goats were able to achieve the expected production. Also,

the surplus of ME 0.51 and 1.11 Mcal.day^{-1} for multiparous and primiparous goats, respectively, can be used for goats for body weight gain.

Regarding the requirement for crude protein, this is 281 g.day^{-1} for multiparous goats and 266 g.day^{-1} for primiparous; the crude protein intake was 295 g.day^{-1} and 298 g.day^{-1}. Thus, according to the NRC (2007), the goats ingested above the required amount of protein.

The digestibility coefficient of dry matter and other nutrients for multiparous and primiparous Saanen goats fed with different levels of CSFA were close to those observed by Silva et al. (2007) who fed goats with Tifton hay (210 g.kg^{-1} CP, 819 g.kg^{-1} NDF) and 500 g.kg^{-1} of CSFA from palm oil added to the diet, and by Molina (2013) who fed goats with oat hay (78 g.kg^{-1}CP, 697 g.kg^{-1} NDF) and 0, 6.25 g.kg^{-1}, 12.5 g.kg^{-1}, 18.75 g.kg^{-1} or 25.0 g.kg^{-1} DM of CSFA from soybean oil. However, other studies have reported higher value for dry matter and nutrient digestibility, such as Sanz Sampelayo et al. (2002) who fed goats with alfalfa hay (210 g.kg^{-1}CP; 450 g.kg^{-1} NDF) and 0, 900 or 1200 g.kg^{-1} DM of a rumen-inert fat in the concentrate, and Souza et al. (2014) who fed goats with corn silage and 0, 28.7 g.kg^{-1} DM, 54.6 g.kg^{-1} DM or 80.5 g.kg^{-1} DM of CSFA.

The average dry matter digestibly (DMD) in this study for multiparous and primiparous goats was 0.65 g.g^{-1} and 0.64 g.g^{-1}, respectively. Silva et al. (2007) and Molina (2013) showed values of 0.63 g.g^{-1} and 0.65 g.g^{-1}, respectively and, with higher values, Sanz Sampelayo et al. (2002) and Souza et al. (2014) showed 0.69 g.g^{-1} of DMD.

The linear positive effect on ether extract intake (EEI) for multiparous and primiparous lactating goats fed with concentrate containing CSFA is explained by the ether extract (EE) content in the concentrate (Table 1). The addition of 15 g of CSFA to the concentrate increases the EE content to 11.8 g.kg^{-1}. This same effect, linear positive, was observed for the ether extract digestibility coefficient (EED). This effect may be associated with a higher concentration of unsaturated fatty acids in CSFA available in the intestine, which have higher solubility in micelles, and thus are more digestible as compared to fatty acids with a higher degree of saturation (Palmquist and Mattos, 2011). The effect observed for EED contributed to the energy values of multiparous diets, which presented a quadratic effect with the addition of CSFA to the concentrate. Because the ether extract contributes 2.25 more energy compared to carbohydrates and

protein, this explains the improvement in the total digestibility of nutrients and increased energy availability for multiparous goats.

The addition of CSFA to the concentrate for multiparous and primiparous goats changed the neutral detergent fiber digestibility coefficient (NDFD); this result shows that forms of rumen-inert lipids cannot decrease cell wall digestibility, as previously shown by Sanz Sampelayo et al. (2002), Souza et al. (2014) and Molina (2013).

The proximity between the average organic matter digestibility (0.67 $g.g^{-1}$ of multiparous and 0.66 $g.g^{-1}$ of primiparous) and total digestible nutrients (0.67 $g.g^{-1}$ of multiparous and 0.67 $g.g^{-1}$ of primiparous) showed that *n*-alkanes are a good marker to estimate dry matter intake and digestibility for grassland goats (Narvaez et al., 2012; Osoro et al., 2013).

The values shown in this study for concentrations of glucose, cholesterol and triglycerides in the blood serum for multiparous and primiparous goats were in the ranges described by Mundim et al. (2007). According to these authors, the reference values for glucose, cholesterol and triglycerides should range between 50 to 75 $mg.dL^{-1}$, 80 to 130 $mg.dL^{-1}$ and 6 to 32 $mg.dL^{-1}$, respectively. Glucose, cholesterol and triglycerides act as indicators of animal energy metabolism. However, serum blood glucose in ruminants shows little change because of the homeostatic regulation of the body; when glucose is released into the bloodstream, the glycemic index is reduced, thus keeping constant levels of glucose (González and Scheffer, 2003). Glucose at levels below to 34 $mg.dL^{-1}$ may indicate ketosis (Tanwar et al., 2000), whereas increased blood glucose may be associated with animal stress due to a decrease in the use of sugar by the animals and increased gluconeogenesis (Canaes et al., 2009).

Therefore, the values obtained for serum glucose (54.35 to 61.94 $mg.dL^{-1}$) show that there was adequate glycemic control, because the values are in agreement with the literature data. Other studies have obtained similar results when feeding goats with CSFA in the diets. Molina (2013) evaluated the effect of adding CSFA to the diet of Saanen goats, with no observed interference in blood glucose, with an average of 50.98 $mg.dL^{-1}$. Similarly, Souza et al. (2014) did not observe changes in serum blood glucose when CSFA rich in polyunsaturated fatty acids was added to increase the dietary energy in the diet of Saanen goats.

The linear increase in blood cholesterol in multiparous Saanen goats fed with CSFA may be related to the increase of available fat in the diet, resulting in an increase in the cholesterol content for the biosynthesis of lipid proteins and transporters of lipids,

thus stimulating the synthesis of cholesterol by enterocytes (Chilliard et al., 1986). This increase in the cholesterol content in response to feeding CSFA has been shown in the literature (Rapetti et al., 2009; Titti, 2011; Souza et al., 2014).

The addition of CSFA to concentrate did not influence the blood triglyceride content in multiparous or primiparous goats, with an average of 23.98 and 25.83 $mg.dL^{-1}$, respectively. The absence of significant variation in plasma triglyceride levels is in agreement with previous results on lactating goats fed with different levels and sources of lipids (Rapetti et al., 2009; Titti, 2011; Molina, 2013; Souza et al., 2014).

The blood urea content is directly correlated to the protein content and energy intake of the diet, and the interaction between these factors. As a protein metabolism indicator, blood urea, which can also be represented as blood urea nitrogen (BUN = urea x 0.466), is the principal final product of protein metabolism in ruminants. Sahlu et al. (1993) reported a positive relationship between the blood urea concentration and the crude protein level in the diet, in which values above or below the recommended limits indicate a protein imbalance in the diet. Contreras et al. (2000) reported that if a diet is deficient in readily available energy, the ammonia concentration in the rumen and the amount of blood urea increase.

The average blood urea content was 53.02 $mg.dL^{-1}$ for multiparous goats and 52.48 $mg.dL^{-1}$ for primiparous goats. Although urea was at a higher concentration than that reported by Mejía et al. (2012), who suggested that the blood urea nitrogenous (BUN) reference values should range between 10 to 21 $mg.dL^{-1}$ (equal to 21 to 45 $mg.dL^{-1}$ urea blood content), the urea still remained within the range of 28 to 104 $mg.dL^{-1}$, observed by Mundim et al. (2007). Similar values have been reported by other authors when CSFA derived from soybean oil was added to the diet of goats in lactation, where Souza (2012) observed values between 25 to 65 $mg.dL^{-1}$ and Molina (2013) observed values between 60 to 65 $mg.dL^{-1}$.

5. Conclusion

These results suggest that CSFA is an alternative energy supplement for feeding lactating goats. For multiparous goats, CSFA did not effectively change grazing behavior did not limit the dry matter intake; however, the addition of 3.5% CSFA (35 $g.day^{-1}$) enhanced the energy value of the diet for multiparous grassland goats. The addition of CSFA to concentrate had little effect on grazing time and did not change the nutritive value of the diet for primiparous Saanen grassland goats.

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Table 1
Average monthly values of meteorological data; maximum (T_{max}) and minimum (T_{min}) temperature (°C), air relative humidity (%) in the morning (RH_m) and in the afternoon (RH_a), days of rain and precipitation total (mm) for the months of October 2011 to January 2012 at Fazenda Experimental de Iguatemi, Maringá-PR

Date	T_{max}	T_{min}	RH_m	RH_a	Days of rain	Precipitation
October 2011	28.3	18.0	82.6	63.4	6	196.4
November 2011	28.8	17.7	81.3	57.4	6	107.0
December2011	31.2	19.6	78.0	53.4	6	53.3
January 2012	28.7	19.4	86.8	65.9	12	135.3

Source: Laboratório de Análises de Sementes - Fazenda Experimental de Iguatemi, of the Universidade Estadual de Maringá. Available on site: http://www.fei.uem.br/

Table 2
Ingredients, chemical composition and *in vitro* digestibility of the concentrate

	Level of calcium salts of fatty acids[1]				
Composition	0.0%	1.5%	3.0%	4.5%	6.0%
Ingredient (g.kg^{-1} DM)					
Ground corn	695.0	676.0	658.0	639.0	621.0
Soybean meal	280.0	284.0	287.0	291.0	294.0
Calcium salts of fatty acids[2]		15.0	30.0	45.0	60.0
Mineral-vitamin supplement[3]	20.0	20.0	20.0	20.0	20.0
Salt	5.0	5.0	5.0	5.0	5.0
Chemical composition (g.kg^{-1} DM)					
Dry matter (g.kg^{-1})	914.5	915.7	921.5	922.5	926.0
Organic matter	951.2	948.3	945.0	943.4	940.2
Ash	48.8	51.7	55.0	56.6	59.8
Calcium	3.7	4.8	5.6	6.6	7.1
Phosphorus	4.7	4.8	4.8	4.8	4.9
Crude protein	188.4	188.6	195.4	189.1	183.4
Ether extract[4]	31.7	43.5	55.4	67.2	79.0
Neutral detergent fibre	106.8	102.7	100.4	112.4	115.2
Non-fibre carbohydrates	624.3	615.8	593.8	574.7	562.6
Total carbohydrates	731.1	718.5	694.3	687.1	677.8
In vitro digestibility (g.g^{-1})					
Dry matter	0.854	0.854	0.848	0.842	0.848
Organic matter	0.879	0.879	0.863	0.864	0.867
Gross energy (Mcal.kg^{-1})	3.87	3.95	3.99	4.07	4.09

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Product commercial Lactoplus®, chemical composition: 3.39 Mcal.kg^{-1} of metabolisable energy, 820 g.kg^{-1}fat, 100 g.kg^{-1} Ca.
[3]Chemical composition (per kg of Caprinofós® with mineral organic): Ca 240 g; P 71 g; F 710 mg (Max); Mg 20 g; K 28.2 g; S 20 g S; Fe 250 mg; Cu 400 mg; Mn 1,350 mg; Zn 1,700 mg; Co 30 mg; I 40 mg; Se 15 mg; Cr 10 mg; Vitamin A 135,000 UI; Vitamin D3 68,000 UI; Vitamin E 450 UI.
[4]From the result of the chemical composition of foods (ground corn and soybean meal) and the composition of the Lactoplus® label.

Table 3
Chemical composition, *in vitro* digestibility and forage mass in Stargrass (*Cynodon nlemfuensis*) of the each experimental period

	Period[1]				
	P1	P2	P3	P4	P5
Chemical composition (g.kg^{-1} DM)					
Dry matter (g.kg^{-1})	338.6	316.0	345.9	372.7	322.8
Organic matter	942.9	937.4	944.5	949.6	939.3
Ash	57.1	62.6	55.5	50.4	60.7
Calcium	2.0	2.1	2.0	2.1	2.0
Phosphorus	2.0	1.8	2.7	2.2	2.6
Crude protein	106.3	117.3	102.0	94.4	123.4
Ether extract	14.0	15.3	14.3	14.5	17.3
Neutral detergent fibre	599.2	614.6	673.0	714.1	679.0
Total carbohydrates	822.6	804.7	828.2	840.8	798.6
Non-fibre carbohydrates	223.4	190.1	155.2	126.7	119.6
In vitro digestibility (g.g^{-1})					
Dry matter	0.600	0.590	0.615	0.559	0.583
Organic matter	0.667	0.666	0.648	0.620	0.620
Sward height (m)	0.35	0.32	0.22	0.21	0.20
Forage mass (kg.DM.ha^{-1})					
Forage mass	4,312	2,592	4,226	2,960	3,608
Forage mass (above 0.15 meters)	1,521	1,349	602	649	706
Leaf blade	569	429	159	239	295
Stem and sheath	709	778	430	346	315
Leaf: Stem ratio	0.80	0.55	0.37	0.69	0.94

[1]Sampling days: P1: 9 October 2011, P2: 1 November 2011, P3: 23 November 2011, P4: 14 December 2011, P5: 3 January 2012.

Table 4
Average values of environmental variables in each experimental period

Environmental variables	Period 1	Period 2	Period 3	Period 4	Period 5
Air temperature (°C)					
Maximum	29.7	28.4	32.4	29.7	32.8
Minimum	23.9	23.9	24.0	25.7	21.4
Average days	26.7	26.8	29.0	28.6	27.2
Black-globe temperature (°C)					
Maximum	40.3	41.7	48.0	44.0	44.0
Minimum	34.0	31.7	34.7	36.3	30.3
Average days	37.0	38.1	40.7	41.5	40.0
Air relative humidity (%)					
Maximum	61.0	68.0	66.0	51.0	81.0
Minimum	46.0	49.0	38.0	34.0	53.0
Average days	53.0	58.7	51.4	40.9	68.7
Wind speed ($m.s^{-1}$)					
Maximum	1.7	1.8	1.9	1.8	2.0
Minimum	0.3	0.7	0.3	0.3	0.7
Average days	1.0	1.0	1.1	0.8	1.2
Temperature of black-globe and humidity index					
Maximum	87.8	90.1	92.0	89.6	93.3
Minimum	81.6	79.2	82.4	83.3	78.1
Average days	84.3	86.1	88.6	87.9	88.9
Radiant thermal load ($W.m^{-2}$)					
Maximum	665.7	680.7	615.3	732.5	740.6
Minimum	526.2	528.2	570.6	550.4	570.0
Average days	600.3	613.4	642.4	633.3	654.7

Period 1: 8 October 2011 to 28 October; Period 2: 29 October to 18 November; Period 3: 19 November to 9 December; Period 4: 10 December to 30 December; Period 5: 31 December to 20 January 2012.

Table 5
Time spent in different grazing behaviours of multiparous and primiparous lactating Saanen goats

Behaviour	Level of calcium salts of fatty acids[1]					SE	*P*-value
	0.0%	1.5%	3.0%	4.5%	6.0%		
Multiparous							
Percentage							
Grazing and drinking water	71.05	74.00	77.85	69.82	67.57	3.17	0.24
Ruminating standing	4.11	4.15	4.10	2.12	3.20	1.61	0.87
Ruminating lying	13.19	10.84	10.66	16.66	16.34	2.79	0.41
Resting standing	6.85	7.27	5.78	8.35	8.93	1.68	0.70
Resting lying	4.81	3.73	1.61	3.03	3.96	2.02	0.84
Time (hours)							
Grazing and drinking water	4.26	4.44	4.67	4.18	4.05	0.19	0.24
Ruminating standing	0.25	0.25	0.25	0.13	0.19	0.10	0.87
Ruminating lying	0.79	0.65	0.64	0.99	0.98	0.18	0.41
Resting standing	0.41	0.44	0.35	0.50	0.54	0.10	0.70
Resting lying	0.29	0.22	0.10	0.18	0.24	0.12	0.84
Primiparous							
Percentage							
Grazing and drinking water	81.95	74.50	77.20	79.14		1.03	0.01[a]
Ruminating standing	3.98	4.00	6.01	4.68		1.03	0.52
Ruminating lying	8.71	12.78	13.44	12.14		1.95	0.40
Resting standing	4.68	7.36	3.34	4.04		1.72	0.44
Resting lying	0.68	1.35	0.00	0.00		0.64	0.45
Time (hours)							
Grazing and drinking water	4.91	4.47	4.63	4.75		0.06	0.01[b]
Ruminating standing	0.24	0.24	0.36	0.28		0.06	0.52
Ruminating lying	0.52	0.77	0.81	0.73		0.12	0.40
Resting standing	0.28	0.44	0.20	0.24		0.10	0.44
Resting lying	0.04	0.08	0.00	0.00		0.04	0.45

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[a]Regression equation: $Y = 81.41 – 5.08x + 1.04x^2$; $r^2 = 0.79$.
[b]Regression equation: $Y = 4.88 – 0.30x + 0.06x^2$; $r^2 = 0.79$.

Table 6
Dry matter and nutrients intake and total apparent digestibility of multiparous Saanen goats in grassland fed by experimental diets

	Level of calcium salts of fatty acids[1]						
	0.0%	1.5%	3.0%	4.5%	6.0%	SE	P-value
Body weight	57.29	56.31	57.05	57.14	57.35	0.54	0.67
Dry matter intake ($kg.day^{-1}$)							
Total DMI	1.94	1.96	2.20	1.90	2.19	0.08	0.06
Forage DMI	1.02	1.04	1.28	0.98	1.26	0.08	0.07
Concentrate DMI	0.92	0.92	0.92	0.92	0.93		
Total DMI ($g.kg^{-1}$ of $BW^{0.75}$)	93.64	95.38	106.85	91.64	105.26	4.32	0.09
Nutrient intake ($kg.day^{-1}$)							
Organic matter	1.83	1.85	2.08	1.79	2.06	0.08	0.06
Crude protein	0.28	0.28	0.32	0.28	0.31	0.01	0.05
Ether extract	0.04	0.06	0.07	0.08	0.09	0.001	<0.01[a]
Neutral detergent fibre	0.76	0.78	0.93	0.74	0.93	0.06	0.07
Total carbohydrates	1.50	1.51	1.69	1.44	1.66	0.07	0.09
Non-fibre carbohydrates	0.74	0.73	0.76	0.69	0.73	0.01	0.06
Total digestible nutrients	1.22	1.33	1.45	1.35	1.44	0.06	0.10
Digestibility coefficient ($g.g^{-1}$)							
Dry matter	0.62	0.68	0.65	0.69	0.63	0.02	0.05
Organic matter	0.64	0.69	0.67	0.71	0.65	0.02	0.05
Crude protein	0.58	0.67	0.64	0.68	0.62	0.02	0.03[b]
Ether extract	0.60	0.73	0.75	0.84	0.81	0.02	<0.01[c]
Neutral detergent fibre	0.50	0.56	0.55	0.59	0.53	0.02	0.06
Non-fibre carbohydrates	0.82	0.84	0.80	0.84	0.80	0.02	0.26
Total carbohydrates	0.66	0.70	0.67	0.71	0.65	0.02	0.09
Energy values of diets ($Mcal.kg^{-1}$)							
Total digestible nutrients ($g.g^{-1}$)	0.63	0.68	0.66	0.71	0.66	0.02	0.02[d]
Digestible energy[2]	2.77	3.01	2.90	3.14	2.89	0.08	0.02[e]
Metabolisable energy[2]	2.35	2.59	2.48	2.73	2.48	0.07	0.02[f]
Net energy for lactation[2]	1.54	1.67	1.61	1.75	1.61	0.04	0.02[g]

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Estimated by NRC (2007) equations.
[a]$Y = 0.04 + 0.01x$, $r^2 = 0.99$.
[b]$Y = 0.59 + 0.05x - 0.01x^2$, $r^2 = 0.76$.
[c]$Y = 0.64 + 0.03x$, $r^2 = 0.80$.
[d]$Y = 0.63 + 0.03x - 0.004x^2$, $r^2 = 0.54$.
[e]$Y = 2.78 + 0.14x - 0.02x^2$, $r^2 = 0.54$.
[f]$Y = 2.36 + 0.15x - 0.02x^2$, $r^2 = 0.54$.
[g]$Y = 1.54 + 0.08x - 0.01x^2$, $r^2 = 0.54$.

Table 7
Dry matter and nutrients intake and total apparent digestibility of primiparous Saanen goats in grassland fed by experimental diets

	Level of calcium salts of fatty acids[1]					
	0.0%	1.5%	3.0%	4.5%	SE	P-value
Body weight	54.05	53.90	53.86	54.03	0.63	0.99
Dry matter intake ($g.day^{-1}$)						
Total DMI	2.04	2.20	2.08	2.10	0.12	0.80
Forage DMI	1.12	1.29	1.16	1.18	0.12	0.80
Concentrated DMI	0.92	0.91	0.92	0.92		
Total DMI ($g.kg^{-1}$ of $BW^{0.75}$)	102.38	110.75	104.38	105.63	5.45	0.74
Nutrient intake ($g.day^{-1}$)						
Organic matter	1.93	2.08	1.96	1.99	0.12	0.80
Crude protein	0.29	0.30	0.30	0.30	0.01	0.87
Ether extract	0.05	0.06	0.07	0.08	0.002	<0.01[a]
Neutral detergent fibre	0.83	0.94	0.85	0.87	0.08	0.79
Total carbohydrates	1.59	1.72	1.59	1.61	0.10	0.78
Non-fibre carbohydrates	0.76	0.78	0.74	0.73	0.02	0.48
Total digestible nutrients	1.29	1.48	1.30	1.42	0.07	0.24
Digestibility coefficient ($g.g^{-1}$)						
Dry matter	0.63	0.67	0.61	0.66	0.02	0.22
Organic matter	0.65	0.68	0.63	0.68	0.02	0.22
Crude protein	0.60	0.62	0.59	0.63	0.02	0.71
Ether extract	0.63	0.71	0.75	0.80	0.03	0.04[b]
Neutral detergent fibre	0.51	0.60	0.50	0.56	0.02	0.06
Total carbohydrates	0.66	0.69	0.64	0.68	0.02	0.17
Non-fibre carbohydrates	0.81	0.79	0.78	0.81	0.02	0.69
Energy values of diets ($Mcal.kg^{-1}$)						
Total digestible nutrients ($g.g^{-1}$)	0.61	0.72	0.66	0.69	0.05	0.56
Digestible energy	2.71	3.19	2.89	3.03	0.24	0.56
Metabolisable energy	2.29	2.77	2.47	2.61	0.24	0.56
Net energy for lactation	1.50	1.77	1.61	1.69	0.13	0.56

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Estimated by NRC (2007) equations.
[a] Regression equation: $Y = 0.05 + 0.007x$, $r^2 = 0.99$.
[b] Regression equation: $Y = 0.64 + 0.37x$, $r^2 = 0.97$.

Table 8
Blood biochemical concentration of multiparous and primiparous lactating Saanen goats in grassland by experimental concentrate

	Level of calcium salts of fatty acids[1]						
mg.dL^{-1}	0.0%	1.5%	3.0%	4.5%	6.0%	SE	P-value
Multiparous							
Glucose	54.33	55.01	58.86	58.32	60.24	3.48	0.71
Cholesterol	75.00	93.55	103.27	99.30	109.97	6.38	0.02[a]
Triglycerides	25.51	20.07	24.45	24.29	25.56	3.06	0.71
Urea	53.75	53.03	52.10	51.37	54.91	2.93	0.92
Calcium	7.83	7.88	8.45	8.16	7.79	0.39	0.73
Phosphorus	3.09	2.84	3.20	3.16	3.44	0.25	0.61
Primiparous							
Glucose	61.94	57.84	61.75	60.66		3.03	0.77
Cholesterol	93.06	101.09	111.51	108.57		4.58	0.10
Triglycerides	23.23	25.96	25.96	28.15		2.57	0.62
Urea	53.65	50.99	53.19	52.09		2.31	0.85
Calcium	9.42	7.93	9.19	8.43		0.51	0.25
Phosphorus	3.23	3.51	3.93	3.65		0.21	0.22

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[a] Regretion equation: $Y = 81.08 + 5.05x$; $r^2=0.81$.

VII – Concentrate with calcium salts of fatty acids from soybean oil increases the concentration of polyunsaturated fatty acids in milk produced by dairy goats in a grazing system

(Normas: Small Ruminant Research)

Abstract

Feeding rumen-inert fat, such as calcium salts of fatty acids (CSFA), has dual benefits as it increases milk yield and improves the fat composition in milk. However, there is a shortage of information on the effect of CSFA on milk yield and composition in grassland Saanen goats . Thus, this study aimed to evaluate the effects of CSFA in the concentrate of lactating grassland Saanen goats on milk yield, composition, quality, and fatty acid composition and to determine the best response to the addition of CSFA. Five multiparous Saanen goats (five years old) were distributed in a 5x5 Latin square design with five treatments (0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA), and four primiparous Saanen goats (three years old) were distributed in a 4x4 Latin square design with four treatments (0%, 1.5%, 3.0% and 4.5% of CSFA); the goats had an average of 78 ± 10 days in lactation at the start of the experiment. Each period lasted 21 days, including 14 days for adaptation and seven days for data collection. Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and CSFA at the levels of inclusion. For grazing goats, an area with Stargrass (*Cynodon nlemfuensis*) was used. The addition of CSFA to the concentrate of grassland Saanen goats had no effect on milk yield, milk components such as fat, protein, lactose and totals solids, or milk quality (acidity and somatic cell counts) in multiparous or primiparous goats. However, the concentration of fatty acids was modified. The concentration of capric (10:0) and myristic (14:0) fatty acids decreased linearly with increased inclusion of CSFA in the concentrate. There was a quadratic effect on medium-chain and long-chain fatty acids and omega-3 (n-3) in the milk of multiparous Saanen goats following treatment. The inclusion of CSFA in the diet of primiparous goats had a positive linear effect for linoleic fatty acid (18:2 n6c), conjugated linoleic acid, omega-6 (n-6) and polyunsaturated fatty acids, whereas the concentration of medium-chain fatty acids showed a negative linear effect. In conclusion, CSFA in the concentrate of grassland primiparous goats showed positive responses on the fatty acid composition of goat milk, increasing the polyunsaturated fatty acid concentration.

Keywords: goat milk fatty acids, grassland, milk components, omega-3, rumen-inert fat

1. Introduction

The consumption of goat milk in Brazil is driven by two factors: goat milk is considered a functional food, and goat milk is used as a raw material for the production of fine cheeses. The functionality of goat milk is due to the lower concentration of allergenic proteins in relation to cow milk, as well as the better fat digestibility of goat milk.

The composition and concentration of proteins is mainly altered by genetic factors, with few effects of diet on milk proteins. However, the milk's fat composition can be easily altered by diet with changes in the amount of fat and fatty acids. Thus, strategies to add sources of fat to the diet of ruminants are a way of modifying the composition of milk fat by increasing the concentration of fatty acids beneficial to human health, such as conjugated linoleic acid (CLA), omega-3, and omega-6 (Novello et al., 2010).

According to Chilliard et al. (2007), feeding dairy ruminants with the addition of unsaturated fatty acids in the ration such as oleic acid (18:1) and linoleic acid (18:2) has been shown to be an efficient strategy to modify milk's fatty acid content. However, the presence of unsaturated fatty acids in the rumen is known to inhibit ruminal microbial activity and fermentation (Yang et al., 2009).

The saponification of long chain fatty acids, typically derived from soybean or palm oils, with calcium ions results in calcium salts, a type of rumen-inert fat with high levels of fatty acids such as palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1) and linoleic acid (18:2). Thus, feeding of calcium salts of fatty acids (CSFA), which are inert in the rumen, can enhance the energy density of the ration and has no negative effects on ruminal fermentation. Increased availability of rumen-inert fatty acids serves a dual benefit, as it increases milk yield and improves the fat composition of milk (Shingfield et al., 2009; Titti, 2011; Souza et al., 2014). There is considerable plasticity in terms of ruminant milk fatty acid composition (Chilliard and Ferlay, 2004).

However, there is a shortage of information on the use of rumen-inert fat on milk yield and composition in grassland Saanen goats. Thus, this study aimed to evaluate the addition of CSFA in the concentrate of multiparous and primiparous lactating grassland Saanen goats on milk yields, composition, quality, fatty acid composition and to determine the best response to the addition of CSFA through the evaluation of the cost and net profits of the concentrate.

2. Material and methods

2.1. Goats and experimental treatments

The experiment was conducted at an experimental farm at the State University of Maringá, southern Brazil. Five multiparous Saanen goats (five years old and on their third lactation; body weight 57 ± 2.7 kg) and four primiparous Saanen goats (three years old; body weight 54 ± 1.8 kg) were sued, with average of 78 ± 10 days in lactation at the start of the experiment. Goats were distributed in two Latin square designs with an experimental period of 21 days, including 14 days for adaptation and seven days for data collection. The multiparous Latin square design was 5x5 with five treatments (0%; 1.5%, 3.0%, 4.5% and 6.0% CSFA) and for the primiparous a 4x4 Latin square design with four treatments (0%, 1.5%, 3.0% and 4.5% CSFA) was used. Goats remained in the pasture for approximately seven hours per day (8:00 am to 3:30 pm) and were housed in individual pens in the evening and overnight. The goats had free access to water in the pasture and pens.

Goats were milked manually twice daily (7:30 am and 3:30 pm) and the milk yield of individual goats was measured using an electronic balance at each milking. After the afternoon milking, goats were fed with the concentrate.

Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and rumen-inert fat in the form of calcium salts of long-chain fatty acids (CSFA) from a commercially available product derived from soybean oil (Lactoplus® from Dalquim Chemical Industry Ltd.; with 1.94 $g.g^{-1}$ total digestible nutrients, 820 $g.kg^{-1}$ ether extract, 100 $g.kg^{-1}$ calcium, 260 $g.kg^{-1}$ oleic acid and 420 $g.kg^{-1}$ linoleic acid); in five levels of inclusion (0%, 1.5%, 3.0%, 4.5% and 6.0% the concentrate) (Table 1). The amount of concentrate offered the goats was established at 1 $kg.day^{-1}$ as feed, or about half of the estimated nutritional requirements of Saanen goats (NRC, 2007) with a body weight of 60 kg and a milk yield of 3.0 $kg.day^{-1}$ with 3.5% fat.

For grazing goats, an area of one hectare (1 ha) was used with the subtropical forage grass Stargrass (*Cynodon nlemfuensis*) maintained by continuous stocking (Table 2). The grassland was fertilized and corrected through physical and chemical analysis of soil and grass demand. Fertilizer was applied at an N-P-K ratio of 8 $kg.ha^{-1}$ of nitrogen, 67 $kg.ha^{-1}$ of phosphorus and 70 $kg.ha^{-1}$ of potassium (200 kg of N-P-K fertilizer 4-20-20; 150 kg of single superphosphate and 50 kg of potassium chloride) in September

2011, which was distributed by throwing 30 days before the input of goats. The grazing period was from 8 October 2011 to 20 January 2012.

The fatty acid composition of the concentrate and forage used are presented in Table 3.

2.2 Sample collection and analyses

Milk samples were collected at the 15th day of each period from each goat for two consecutive milking and pooled on a yield basis.

For the chemical composition determination, milk samples were stored at 4ºC with a preservative (2-bromo-2-nitropropane-1.3-diol) until analysed for fat, protein, lactose and total solids by infrared spectroscopy (Bentley model 2000; Bentley Instrument Inc. Chaska. MN). Milk's somatic cells counts (SCC) were obtained using an electronic counter (Somacount 500. Chaska. MN), which was calibrated for cow milk analysis. At the same time milk acidity, using the Dornic solution, was measured according to (AOAC, 1998) method no. 947.05.

Another two milk samples were collected and frozen without addition of preservatives, one were used to analysed the milk urea nitrogen, and the other one to determine the milk fat composition.

Milk samples were centrifuged for 30 min at 3,000 rpm at 4°C and the serum was separated and frozen for subsequent analyses. Concentration of milk urea nitrogen was analysed using commercial kits (urea-PP kit category 427; Gold Analisa Diagnostica®) in spectrophotometer (Shimadzu UV-1601 UV-Visable Spectrophotometer®).

Milk fat composition was extracted by centrifugation (Murphy et al., 1995), and the transesterification according to (ISO, 2000) method n° 5509 with KOH/methanol and n-heptane. Thereafter, the methyl ester composition of fatty acids were measured by gas chromatography (Trace GC Ultra, Thermo Scientific, USA) equipped with an auto sampler, a flame ionization detector at 240°C and a fused-silica capillary column (100 m long, 0.25 mm internal diameter and 0.20 μm film thickness, Restek 2560®).

Fatty acids were quantified $g.100g^{-1}$ lipids, compared to the retention time of methyl ester's fatty acids from the sample standards tricosanoic acid methyl ester (23:0) (Sigma Aldrich®, Brazil). The column parameters were as follows: initial column temperature of 65°C was maintained for 8 min; the temperature was then programmed at 50°C/min to 170°C; this temperature was maintained for 40 min and then increased 50°C/min to 240°C and remained for 28.5 min. Injector and detector temperatures were

220 and 245°C, respectively. The gas flow was 1.5 ml/min for hydrogen (carrier gas), 30 ml/min for N_2 (auxiliary gas), 35 ml/min for H_2 and 350 ml/min for compressed air. With a microliter syringe 2 μL of samples were inject with a split ratio of 1:100. Fatty acid peaks were identified by comparison of the retention times of pure methyl ester standards (Sigma Aldrich®, Brazil).

The milk yield was corrected to 4.0% of fat according to NRC (2007) that used the NRC (2001) equation: FCM (4.0%) = (0.4 x MY)+ (15 x ((FY x MY)/100)); where FCM: fat corrected milk to 4.0% of fat ($kg.day^{-1}$); MY: milk yield ($kg.day^{-1}$); FY: fat yield ($kg.day^{-1}$).

The net energy of milk (NE_{milk}), energy contained in the milk produced, is equivalent to the sum of the heats of combustion of individual milk components (fat, protein, and lactose) is calculated according to the (NRC, 2001) equation: VE_{milk} (Mcal/kg) = (0.0929 x Fat %) + (0.0547 x Protein %) + (0.0395 x Lactose %).

Sampling of the forage, for the chemical analysis and manual separation of morphological components (leaf blade, stem and sheath, dead material), were collected once in each experimental period (9 October 2011, 1 November 2011, 23 November 2011, 14 December 2011, 3 January 2012); to ensure random sampling, one 1.0 m² wire square was thrown eight times in the paddock and the grass was cut 15 cm above the ground. Samples of forage to determine total forage mass was cut close to the soil. The sward height was measured with a wooden ruler graduated in centimetres in 20 random points. And for chemical analysis samples of concentrate were taken each experimental period and polled by concentrate.

Samples of forage each period were oven-dried (55°C for 72 h), then ground through a 1-mm screen in a Wiley mill. Concentrate were ground through a 1-mm screen in a hammer mill. Dry matter was determined according to the method no. 934.01 of AOAC (1998). Ash was determined by combustion in a muffle furnace according to method no. 942.05 (AOAC, 1998). Calcium and phosphorus were analysed by using acid digestion with nitric and perchloric acid (1:2). After that, they were filtered to obtain a mineral solution. Calcium and phosphorus readings were obtained by using atomic absorption (spectrophotometer GBC 932 AA in flame air-acetylene) and colorimetric (spectrophotometer Shimadzu UV-1601 UV-Visable Spectrophotometer®), respectively, according to (AOAC, 1990). Total nitrogen (TN) was evaluated using a Tecnal TE-036/1 (Tecnal, Piracicaba, São Paulo, Brazil) following method no. 988.05 of (AOAC, 1998) and crude protein (CP) was estimated as

TN x 6.25. The ether extract (EE) was conducted with Tecnal TE-044/1 according to the method no. 920.39 of the (AOAC, 1998). The neutral detergent fibre (NDF) was evaluated as described by Van Soest et al. (1991) without the use of sodium sulphite and with the inclusion of heat-stable α-amylase. Total carbohydrates (TC) was estimated according to equations described by Sniffen et al. (1992): TC ($g.kg^{-1}$ of DM) = 1000 - (CP + EE + ash). Gross energy content was determined by combustion in a adiabatic bomb calorimeter (Parr Instrument Co.AC720®, Parr Instrument Company, USA).

The *in vitro* dry matter and organic matter digestibility (*IV*DMD and *IV*OMD, respectively) of the five concentrate and Stargrass were determined according to the procedure described by Tilley and Terry (1963) by using in an Artificial Rumen (ANKOM Technology®, Macedon, New York, USA) according to Santos et al. (2000). The rumen fluid used as inoculum was drawn from the rumen of the three Saanen-Boer goats with a rumen cannula, fed with Stargrass grassland, and transferred into pre-warmed thermos bottles. The *in vitro* digestibility (*IV*D) was calculated as the difference between the incubated and residue amount of feed using the following formula: *IV*D =100 – [(W3 – (W1 × W4)) × 100/W2], where W1 is the filter weight empty; W2 is the sample weight; W3 is the filter final weight; and W4 is the correction filter blank.

2.3. Economic evaluation

The economic evaluation was performed based on the concept of net profit (Cimmyt, 1988), described by Borges et al. (2004). The net profit is related to the revenue (value of milk production in the treatment) minus the variable costs, which are costs that differ according to the treatment. The cost of food per kilogram of feed was quoted in February 2012 for the region of Maringá in Brazilian Reais (R$) and converted into United States dollars (US$) (1.00 US$ is equal 1.97 R$): ground corn, 0.22 $US\$.kg^{-1}$ as feed; soybean meal, 0.50 $US\$.kg^{-1}$ as feed; CSFA, 1.76 $US\$.kg^{-1}$as feed; mineral-vitamin supplement, 0.85 $US\$.kg^{-1}$ as feed; and limestone, 0.24 $US\$.kg^{-1}$ as feed. For goat milk, the same value, 0.74 $US\$.kg^{-1}$, was used for all the treatments, as it is paid by the dairy CAPRILAT®. So, the food cost of each concentrate, 0%; 1.5%, 3.0%; 4.5% and 6.0%, was 0.31 $US\$.kg^{-1}$, 0.34 $US\$.kg^{-1}$, 0.36 $US\$.kg^{-1}$, 0.38 $US\$.kg^{-1}$, 0.41 $US\$.kg^{-1}$ as feed.

2.4. Statistical Analysis

The data were analyzed by analysis of variance, linear curve estimation and quadratic regression equations ($\alpha = 0.05$) with the general model: $Y_{ijkl} = \mu + T_i + P_j + A_l + e_{ij}$ where: Y_{ijkl} = the dependent variable, μ = general constant, D_i = effect of concentrate *i*, P_j= effect of period *j*, Al = effect of animal *l* and e_{ijkl} = random error.

3. Results

The addition of rumen-inert fat as CSFA to the concentrate of multiparous grassland Saanen goats had no effect on milk yield, milk components, or the levels of protein, fat, lactose and total solids (Table 4). Urea nitrogen, somatic cell counts, acidity and net milk energy values were similar among treatments.

Although the addition of CSFA did not influence the fat content of milk, the concentration of fatty acids was modified. The treatment of multiparous grassland Saanen goats was not influenced in terms of the concentrations of saturated, monounsaturated and polyunsaturated fatty acids (Table 5). However, the fatty acids capric acid (10:0) and myristic acid (14:0) the concentration decreased linearly due to the increased inclusion of CSFA on concentrate. The concentrations of other fatty acids were not affected by the treatments. Nevertheless, there was a negative linear effect on medium-chain and a positive linear effect on long-chain fatty acids, whereas short-chain fatty acids were not affected.

The conjugated linoleic acid, omega-6 (*n*-6) and the *n*-6/*n*-3 ratio were not affected by the treatments; however, there was a quadratic effect on the concentration of omega-3 (*n*-3) in milk from multiparous grassland Saanen goats fed rumen-inert fat.

Similar to multiparous goats, the treatment of primiparous grassland Saanen goats had no effect on milk yield, milk components, and the levels of protein, fat, lactose and total solids (Table 6). Urea nitrogen, somatic cell counts, acidity and the energy value of milk were similar among treatments. However, for the fatty acid composition, different results were found for primiparous goats relative to multiparous goats (Table 7). The addition of rumen-inert fat in the form of calcium salts to the diet of primiparous goats had a positive linear effect for the fatty acids linoleic acid (18:2n6c), conjugated linoleic acid, omega-6 (n-6) and polyunsaturated fatty acids, whereas the concentrations of medium-chain fatty acids showed a negative linear effect. As for all the other fatty acids, there was no influence of calcium salts on the diet of primiparous goats.

4. Discussion

The milk yield was not modified by the addition of rumen-inert fat in the form calcium salts in the concentrate of multiparous or primiparous grassland Saanen goats, which produced 2.8 and 2.7 kg.day^{-1} of milk, respectively. These results agree with those presented by Chilliard et al. (2003) in that supplementation of goats with lipids in middle and late lactation had no effect on milk production; similar results were also shown by Molina (2013). However, there are contradictions in the literature: Titti (2011) fed Shami goats during early and mid-lactation with 0 g.kg^{-1}, 30 g.kg^{-1} and 50 g.kg^{-1} of calcium salts (0 g.day^{-1}, 45 g.day^{-1} or 75 g.day^{-1}) and Souza et al. (2014) fed Saanen goats from 0 to 110 g.day^{-1} of CSFA based on soybean oil and observed a positive effect of lipid supplementation on milk production.

The lack of differences in milk production may be due to the similar metabolizable energy intake in the concentrate (2.01 Mcal.kg^{-1}). Similarly, Sanz Sampelayo et al. (2002) showed that lactating goats fed diets containing different amounts of rumen-inert long fatty acids in the form of calcium salts, observed no increase in milk yield. According to these authors, this result was due to similar metabolizable energy intakes among the diets, since the energy of the diet is one of the main factors limiting the production of milk.

These productions are close to the nutritional requirements estimated for Saanen goats (NRC, 2007) at the beginning of the experiment, with a milk yield of 3.0 kg.day^{-1}; thus, the concentrate was able to meet the nutritional requirements. If we consider that *in vitro* digestibility of organic matter is one estimate of total digestible nutrients (TDN) for the concentrate, and using the formula described by NRC (2001) to estimate the net energy of feeds ($NE_{Mcal/kg}$ = 0.0245 x %TDN - 0.12) the average net energy of the concentrate was 2.01 Mcal.kg^{-1} and was able to meet the NE requirements for multiparous and primiparous goats, i.e. 1.71 Mcal.kg^{-1} and 1.57 Mcal.kg^{-1}, respectively.

Other variables that were not affected by the use of CSFA in the concentrate of multiparous and primiparous grassland Saanen goats were the concentration of milk components and the levels of protein, fat, lactose and total solids. This result does not agree with other studies that investigated the addition of CSFA based on soybean oil to the diet of goats (Souza, 2012; Molina, 2013), as a linear reduction in the protein content of the milk was observed with the addition of rumen-inert fat to the diet of lactating goats. These different responses may be associated with the forage and the amount of CSFA administered. Souza (2012) fed Saanen goats a diet containing 60%

corn silage and 0, 2.8, 5.5 or 8.1% CSFA in the diet. Molina (2013) fed Saanen goats s diet containing 57% oat hay and 0, 0.6, 1.3, 1.9 or 2.5% CSFA. Sanz Sampelayo et al. (2002), Titti (2011), Souza (2012) and Molina (2013) observed an increase in the milk fat content in goats supplemented with CSFA. These differences among studies may be due to the amount of the concentrate taken in by goats. In this study, goats were fed once daily with 1 kg of the concentrate, which may have caused the inhibition of acetic acid production in the rumen, which one of the precursors of milk fat. However, other factors in addition to the composition of the diet may also influence milk composition, such as the genotype for αS1-casein, which affects the protein and fat contents (Silva et al., 2009; Berget et al., 2010).

The milk urea nitrogen (MUN) results in this study ranged from 16.53 to 20.86 $mg.dL^{-1}$ and were all above 16.0 $mg.dL^{-1}$, with an average of 18.0 $mg.dL^{-1}$ for multiparous and 17.69 $mg.dL^{-1}$ for primiparous goats. MUN has been used as an indicator of the adequacy of crude protein in the diet. According to Bonanno et al. (2010) and Giaccone et al. (2010), the MUN concentration in goat milk should range from 9.7 to 35.4 $mg.dL^{-1}$. MUN is positively correlated with the crude protein content in the diet, the forage allowance, diet net energy for lactation concentration, milk yield, parity, stage of lactation and forage chemical variations and is negatively related to neutral detergent fiber and diet digestibility. However, in studies on goats, a very wide range has been observed for MUN; the ideal range for MUN in milk goats has not been conclusively determined.

The average for somatic cells counts (SCC) of multiparous and primiparous Saanen goats fed with concentrate containing rumen-inert fat in the form calcium salts was 3.05 log10 cells/mLx1000, corresponding to 1,122,000 $cells.mL^{-1}$. Although there are no official limits for the SCC of goat milk in Brazil (Brasil, 2000), this is a high result that is not suitable for international standards. In the United States of America, the limit established for SCC in goats by the FDA (2010) is 1,000,000 $cells.mL^{-1}$. Studies in the US and EU examined non-infectious factors contributing to elevations in cell counts; Paape et al. (2007) verified that non-infectious factors such as parity and stage of lactation have a major impact on cell counts in goats, and need to be considered when establishing legal limits.

Changes in the fatty acid (FA) concentration of milk fat were typical of those reported in studies where goats were fed with rumen-inert fat in the form of calcium salts (Shingfield et al., 2009; Titti, 2011; Souza et al., 2014).

With the addition of CSFA to the concentrate, there was a reduction in the levels of capric (10:0) and myristic (14:0) fatty acids; these are classified as short chain saturated fatty acids. A decrease in the levels of capric and myristic acid can improve the taste of goat milk (Chilliard et al., 2003). This is also interesting from the viewpoint of human nutrition, since these fatty acids cause an increase in the plasma concentration of low density lipoprotein (LDL) cholesterol.

Supplementation of multiparous goats with calcium salts favored the production of milk with higher levels of the essential fatty acid omega-3 (n-3); this fatty acid could play a role in human health.

Regarding the degree of saturation of the fatty acids in milk fat, the averages observed for multiparous goats were 68.47 $g.100g^{-1}$, 22.24 $g.100g^{-1}$ and 9.28 $g.100g^{-1}$, for saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids, (PUFA), respectively, while for primiparous goats, the results were SFA (68.22 $g.100g^{-1}$), MUFA (22.46 $g.100g^{-1}$) and PUFA (8.61 $g.100g^{-1}$). These results are interesting in terms of human nutrition, as reported by Queiroga et al. (2007) who observed higher values for SFA (75.91 $g.100g^{-1}$) and lower values for MUFA (21.89 $g.100g^{-1}$) and PUFA (2.19 $g.100g^{-1}$). Studies show that MUFA and PUFA fatty acids are associated with beneficial effects on LDL and HDL cholesterol and the incidence of cardiovascular stroke (Lima et al., 2000). Castro et al. (2004) also mentioned that polyunsaturated fat and monounsaturated fat are related to lower risks of heart disease.

The various changes observed for multiparous and primiparous goats in the composition of some fatty acids present in milk fat show that the inclusion of calcium salts partially interfered in the *de novo* synthesis of some fatty acids. It is likely that the calcium salts may have influenced the production of acetate and β-hydroxybutyrate, precursors for the *de novo* synthesis of fatty acids by epithelial cells in the mammary gland (Palmquist et al., 1993). However, factors others than diet, such as parity, breed, genotype, stage of lactation and the expression of genes may also influence lipogenesis in the mammary gland of goats (Chilliard et al., 2003; Bernard et al., 2013). This may explain the different responses in this study in terms of the milk fatty acid composition in multiparous and primiparous goats.

Stearic fatty acid (18:0) was the main fatty acid found in the milk of goats supplemented with CSFA. The average values observed for multiparous and primiparous goats were 24.16 $g.100g^{-1}$ and 23.77 $g.100g^{-1}$, respectively. However, even

though this is a saturated fatty acid with a long chain, it is rapidly converted into oleic acid, which is not a risk to human health (Castro et al., 2004). The fatty acid stearic (18:0) is also responsible for the concentrations of milk oleic fatty acid (18:1n9c), because the activity of the enzyme Δ9-desaturase in the mammary gland catalyzes the insertion of a double bond in this molecule, thereby converting stearic acid into oleic acid. The concentration of oleic acid in the milk of goats supplemented with CSFA was 18.36 g.100g^{-1} and 18.20 g.100g^{-1} for primiparous and multiparous goats, respectively, which makes this the second most prevalent fatty acid in the milk in this study.

The economic evaluation was based on the concept of net benefit, which corresponds to the revenue (value of milk production) subtracted from the differential costs; that is, costs that vary according to the concentrated feed. The costs of the ration concentrate as feed were 0.31 US$.kg^{-1}, 0.34 US$.kg^{-1}, 0.36 US$.kg^{-1}, 0.38 US$.kg^{-1}, 0.41 US$.kg^{-1}, respectively, for the 0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA concentrates. Although the cost of each concentrate was different among treatments, the difference of 0.10 US$.kg^{-1} between the cheapest and most expensive diet did not have an effect on the net profit of milk. However, in multiparous and primiparous goats fed with 1.5% calcium salts in the concentrate, the net benefit was numerically greater than that of the other treatments. The difference in net benefit between the treatment with 1.5% calcium salts and the treatment without calcium salts was 19 cents a day. In one month, this represents approximately 2.89 US$ per goat, so throughout one year and in herds with a large number of goats, this will make a difference in terms of cash flow.

5. Conclusion

The data suggest that the addition of rumen-inert fat in the form of CSFA in the pelleted concentrate of multiparous grassland Saanen goats does not change the milk yield, milk composition or milk quality. However, CSFA in the concentrate of primiparous grassland goats showed positive responses in terms of the fatty acid composition of the milk, with increased concentrations of polyunsaturated fatty acids and conjugated linoleic acid. Multiparous or primiparous goats fed with 1.5% CSFA in the concentrate showed a net benefit that was numerically greater than the other treatments.

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Table 1
Ingredients, chemical composition and *in vitro* digestibility of the concentrates

	Level of calcium salts of fatty acids[1]				
Composition	0.0%	1.5%	3.0%	4.5%	6.0%
Ingredient (g.kg^{-1} DM)					
Ground corn	695.0	676.0	658.0	639.0	621.0
Soybean meal	280.0	284.0	287.0	291.0	294.0
Calcium salts of fatty acids[2]		15.0	30.0	45.0	60.0
Mineral-vitamin supplement[3]	20.0	20.0	20.0	20.0	20.0
Salt	5.0	5.0	5.0	5.0	5.0
Chemical composition (g.kg^{-1} DM)					
Dry matter (g.kg^{-1})	914.5	915.7	921.5	922.5	926.0
Organic matter	951.2	948.3	945.0	943.4	940.2
Ash	48.8	51.7	55.0	56.6	59.8
Calcium	3.7	4.8	5.6	6.6	7.1
Phosphorus	4.7	4.8	4.8	4.8	4.9
Crude protein	188.4	188.6	195.4	189.1	183.4
Ether extract[4]	31.7	43.5	55.4	67.2	79.0
Neutral detergent fibre	106.8	102.7	100.4	112.4	115.2
Non-fibre carbohydrates	624.3	615.8	593.8	574.7	562.6
Total carbohydrates	731.1	718.5	694.3	687.1	677.8
In vitro digestibility (g.g^{-1})					
Dry matter	0.854	0.854	0.848	0.842	0.848
Organic matter	0.879	0.879	0.863	0.864	0.867
Gross energy (Mcal.kg^{-1})	3.87	3.95	3.99	4.07	4.09

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Product commercial Lactoplus®, chemical composition: 3.39 Mcal.kg^{-1} of metabolisable energy, 820 g.kg^{-1}fat, 100 g.kg^{-1} Ca, 60 g.kg^{-1} oleic acid and 420 g.kg^{-1} linoleic acid.
[3]Chemical composition (per kg of Caprinofós® with mineral organic): Ca 240 g; P 71 g; F 710 mg (Max); Mg 20 g; K 28.2 g; S 20 g S; Fe 250 mg; Cu 400 mg; Mn 1,350 mg; Zn 1,700 mg; Co 30 mg; I 40 mg; Se 15 mg; Cr 10 mg; Vitamin A 135,000 UI; Vitamin D3 68,000 UI; Vitamin E 450 UI.
[4]From the result of the chemical composition of foods (ground corn and soybean meal) and the composition of the Lactoplus® label.

Table 2
Chemical composition, *in vitro* digestibility and forage mass in Stargrass (*Cynodon nlemfuensis*) of the each experimental period

	Period[1]				
	P1	P2	P3	P4	P5
Chemical composition ($g.kg^{-1}$ DM)					
Dry matter (g.kg-1)	338.6	316.0	345.9	372.7	322.8
Organic matter	942.9	937.4	944.5	949.6	939.3
Ash	57.1	62.6	55.5	50.4	60.7
Calcium	2.0	2.1	2.0	2.1	2.0
Phosphorus	2.0	1.8	2.7	2.2	2.6
Crude protein	106.3	117.3	102.0	94.4	123.4
Ether extract	14.0	15.3	14.3	14.5	17.3
Neutral detergent fibre	599.2	614.6	673.0	714.1	679.0
Total carbohydrates	822.6	804.7	828.2	840.8	798.6
Non-fibre carbohydrates	223.4	190.1	155.2	126.7	119.6
In vitro digestibility ($g.g^{-1}$)					
Dry matter	0.600	0.590	0.615	0.559	0.583
Organic matter	0.667	0.666	0.648	0.620	0.620
Sward height (m)	0.350	0.320	0.220	0.210	0.200
Forage mass ($kg.DM.ha^{-1}$)					
Forage mass	4312	2592	4226	2960	3608
Forage mass (above 0.15 meters)	1521	1349	602	649	706
Leaf blade	569	429	159	239	295
Stem and sheath	709	778	430	346	315
Leaf: Stem ratio	0.80	0.55	0.37	0.69	0.94

[1]Sampling days: P1: 9 October 2011, P2: 1 November 2011, P3: 23 November 2011, P4: 14 December 2011, P5: 3 January 2012.

Table 3
Fatty acids composition of the concentrates of the concentrates and Stargrass (*Cynodon nlemfuensis*)

	Level of calcium salts of fatty acids[1]					
g.100g^{-1} of fatty acids	0.0%	1.5%	3.0%	4.5%	6.0%	Stargrass
14:0, myristic	0.12	0.16	0.33	0.26	0.25	0.26
16:0, palmitic	20.42	24.22	23.18	26.33	23.97	22.80
18:0, stearic	5.80	6.84	8.77	7.33	8.14	6.48
18:1n-9c, oleic	36.00	38.26	33.81	35.18	28.23	34.40
18:2n-6, linoleic	26.63	19.89	21.12	22.37	21.65	28.71
18:3n-3, linolenic	1.47	1.46	1.11	1.73	1.52	1.85
20:4, araquidonic	1.44	1.73	1.94	1.40	1.16	1.20

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

Table 4
Milk yield and composition of multiparous Saanen goat fed experimental concentrate in grassland

	Level of calcium salts of fatty acids[1]					SE	P-value
	0.0%	1.5%	3.0%	4.5%	6.0%		
Yield ($kg.day^{-1}$)							
Milk yield	2.74	2.90	2.88	2.79	2.68	0.10	0.46
Milk yield $_{\text{corrected to 4.0\% of fat}}$	2.38	2.56	2.57	2.46	2.30	0.11	0.41
Milk composition ($g.kg^{-1}$)							
Protein	27.44	27.70	27.92	27.78	27.06	0.47	0.72
Urea nitrogen ($mg.dL^{-1}$)	20.86	17.73	17.37	16.53	17.50	0.94	0.06
Fat	31.22	32.14	32.94	31.84	30.68	1.58	0.87
Lactose	40.92	41.00	41.02	41.56	41.42	0.27	0.41
Total solid	107.16	108.50	109.64	108.98	106.88	1.87	0.81
Calcium ($mg.dL^{-1}$)	21.90	22.77	22.29	21.16	22.03	0.41	0.15
Phosphorus ($mg.dL^{-1}$)	21.05	17.50	22.16	22.35	20.60	2.03	0.48
Calcium:Phosphorus	1.06	1.39	1.03	0.98	1.13	0.12	0.21
Components yield ($g.day^{-1}$)							
Protein	74.62	80.03	80.14	77.54	72.53	3.49	0.48
Fat	85.49	93.28	94.44	89.16	81.97	5.58	0.50
Lactose	111.26	118.46	117.29	115.58	110.67	3.84	0.52
Total solid	291.99	313.86	314.01	303.98	285.84	12.42	0.42
Milk somatic cells $counts_{(log10)}$	3.07	3.12	2.98	2.87	3.07	0.13	0.66
Acidity (°D)	13.29	13.65	13.99	13.59	14.35	0.65	0.81
Net energy of milk ($Mcal.kg^{-1}$)	0.60	0.61	0.62	0.61	0.60	0.02	0.83
Net profit of milk (US$)	1.71	1.80	1.77	1.68	1.56	0.07	0.23

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

Table 5
Fatty acids in milk of multiparous Saanen goats fed experimental concentrate in grassland

	Level of calcium salts of fatty acids[1]						*P*-
g.100g^{-1} of fatty acids	0.0%	1.5%	3.0%	4.5%	6.0%	SE	value
6:0, caproic	0.82	0.90	0.86	0.72	0.74	0.08	0.44
8:0, caprilic	2.16	2.05	1.89	1.91	2.06	0.21	0.88
10:0, capric	11.04	10.97	10.67	10.46	10.16	0.14	0.01[a]
12:0, lauric	5.05	4.96	4.95	5.01	4.94	0.05	0.42
14:0, myristic	15.24	15.06	14.76	14.75	14.26	0.13	<0.01[b]
16:0, palmitic	10.26	10.78	9.94	9.44	9.63	0.37	0.16
18:0, stearic	23.78	23.69	24.04	24.71	24.57	0.31	0.12
18:1n9t, laidic	2.61	2.55	2.58	2.57	2.55	0.02	0.16
18:1n9c, oleic	17.91	18.10	18.57	18.15	18.26	0.35	0.75
18:2n9c, linoleic	0.24	0.25	0.25	0.26	0.26	0.01	0.31
18:2n6c, linoleic	6.81	6.96	7.24	7.64	7.95	0.47	0.44
18:3n3, α-linolenic	0.26	0.26	0.31	0.38	0.34	0.05	0.41
18:3n6, γ-linolenic	0.61	0.62	0.74	0.75	0.71	0.05	0.20
20:0, eicosanoic	0.24	0.25	0.28	0.29	0.32	0.03	0.31
20:2	0.29	0.32	0.39	0.42	0.46	0.04	0.06
20:3n6	0.17	0.18	0.18	0.23	0.19	0.03	0.68
Others fatty acids	2.64	2.25	2.51	2.49	2.70	0.10	0.06
Conjugated linoleic acid. CLA	7.05	7.21	7.49	7.89	8.21	0.47	0.43
n-3. omega 3	0.31	0.32	0.37	0.46	0.42	0.05	0.18
n-6. omega 6	7.63	7.80	8.21	8.71	8.93	0.51	0.35
n-6 / *n*-3	29.60	29.57	26.44	20.00	23.09	4.58	0.53
Saturated fatty acids. SFA	69.36	69.28	68.03	68.10	67.58	0.77	0.40
Monounsaturated fatty acids. MUFA	22.14	22.03	22.74	21.99	22.29	0.39	0.66
Polyunsaturated fatty acids. PUFA	8.49	8.70	9.23	9.90	10.08	0.54	0.21
Short-chain fatty acids. SCFA	19.33	18.99	18.52	18.40	18.12	0.36	0.19
Medium-chain fatty acids. MCFA	27.26	27.35	26.26	25.37	25.44	0.44	0.02[c]
Long-chain fatty acids. LCFA	53.40	53.68	55.22	56.23	56.38	0.74	0.04[d]

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[a]Regression equation: $Y = 11.11 - 0.15x$; $r^2=0.97$.
[b]Regression equation: $Y = 15.27 - 0.15x$; $r^2=0.93$.
[c]Regression equation: $Y = 27.46 - 0.37x$; $r^2=0.87$.
[d]Regression equation: $Y = 53.26 + 0.57x$; $r^2=0.94$.

Table 6
Milk yield and composition of primiparous Saanen goats fed experimental concentrate in grassland

	Level of calcium salts of fatty acids[1]				SE	P-value
	0.0%	1.5%	3.0%	4.5%		
Yield ($kg.day^{-1}$)						
Milk yield	2.60	2.80	2.69	2.59	0.09	0.37
Milk yield $_{\text{corrected to 4.0\% of fat}}$	2.16	2.34	2.23	2.15	0.08	0.40
Milk components ($g.kg^{-1}$)						
Protein	27.48	26.83	27.38	27.43	0.30	0.46
Urea nitrogen ($mg.dL^{-1}$)	17.06	19.15	16.55	18.00	1.55	0.67
Fat	29.02	29.25	28.45	28.70	0.62	0.81
Lactose	40.50	40.13	39.83	40.05	0.30	0.51
Total solid	104.75	103.93	103.28	103.90	1.09	0.82
Calcium ($mg.dL^{-1}$)	20.61	21.44	19.95	19.60	1.18	0.72
Phosphorus ($mg.dL^{-1}$)	17.61	21.41	17.41	21.36	1.74	0.27
Calcium:Phosphorus	1.26	1.01	1.14	0.98	0.07	0.11
Milk components yield ($g.day^{-1}$)						
Protein	70.52	74.54	72.84	70.52	2.14	0.52
Fat	74.77	81.43	76.78	73.91	3.27	0.43
Lactose	104.59	112.03	106.99	103.35	3.48	0.38
Total solid	269.66	289.68	277.11	267.59	9.27	0.40
Milk somatic cells counts $_{(\log 10)}$	3.12	3.04	3.06	3.09	0.09	0.93
Acidity (°D)	14.40	14.08	14.45	14.80	0.29	0.45
Net energy of milk ($Mcal.kg^{-1}$)	0.58	0.58	0.57	0.57	0.01	0.87
Net profit of milk (US$)	1.60	1.73	1.62	1.53	0.06	0.27

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

Table 7
Fatty acids in milk of primiparous Saanen goats fed experimental concentrate in grassland

	Level of calcium salts of fatty acids[1]					
g.100g^{-1} of fatty acids	0.0%	1.5%	3.0%	4.5%	SE	*P*-value
6:0, caproic	0.84	0.85	0.83	0.84	0.05	0.99
8:0, caprilic	2.33	2.29	1.95	2.01	0.24	0.62
10:0, capric	10.59	10.70	10.71	10.21	0.25	0.50
12:0, lauric	5.06	5.04	5.20	4.87	0.08	0.14
14:0, myristic	15.72	15.54	14.97	14.46	0.47	0.31
16:0, palmitic	10.05	10.10	9.90	8.94	0.42	0.26
18:0, stearic	24.14	23.92	24.03	22.98	0.48	0.37
18:1n9t, laídico	2.63	2.64	2.69	2.54	0.05	0.22
18:1n9c, oleic	18.35	19.23	17.46	18.41	1.17	0.77
18:2n9c, linoleic	0.29	0.11	0.13	0.29	0.12	0.64
18:2n6c, linoleic	5.75	5.27	7.83	7.28	0.40	0.01[a]
18:3n3, α-linolenic	0.32	0.33	0.33	0.30	0.02	0.73
18:3n6, γ-linolenic	0.68	0.76	0.67	0.78	0.08	0.68
20:0, eicosanoic	0.25	0.26	0.33	0.43	0.08	0.48
20:2	0.40	0.42	0.44	0.33	0.03	0.12
20:3n6	0.20	0.22	0.21	0.20	0.03	0.91
Others fatty acids	2.78	2.75	2.18	2.43	0.09	0.01[b]
Conjugated linoleic acid. CLA	6.03	5.39	7.96	7.56	0.36	0.01[c]
n-3. omega 3	0.42	0.40	0.44	0.41	0.04	0.90
n-6. omega 6	6.68	6.32	8.76	8.34	0.43	0.02[d]
n-6 / *n*-3	16.54	16.37	21.18	21.55	1.88	0.18
Saturated fatty acids. SFA	69.70	69.36	68.49	65.33	1.32	0.18
Monounsaturated fatty acids. MUFA	22.64	23.55	21.31	22.34	1.14	0.61
Polyunsaturated fatty acids. PUFA	7.75	7.21	9.90	9.59	0.29	0.001[e]
Short-chain fatty acids. SCFA	18.91	18.98	18.78	18.02	0.54	0.60
Medium-chain fatty acids. MCFA	27.55	27.36	25.89	24.76	0.58	0.04[f]
Long-chain fatty acids. LCFA	53.67	53.83	54.90	54.25	0.90	0.78

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[a]Regression equation: $Y = 5.46 + 0.48x$; $r^2=0.57$.
[b]Regression equation: $Y = 2.78 – 0.11x$; $r^2=0.54$.
[c]Regression equation: $Y = 5.66 + 0.48x$; $r^2=0.57$.
[d]Regression equation: $Y = 6.41 + 0.49x$; $r^2=0.63$.
[e]Regression equation: $Y = 7.38 + 0.55x$; $r^2=0.63$.
[f]Regression equation: $Y = 27.86 - 0.65x$; $r^2=0.93$.

VIII – Concentrate containing calcium salts of fatty acids rich in polyunsaturated fatty acids can change rumen fermentation in grazing goats

(Normas: Small Ruminant Research)

Abstract

Feeding goats with rumen-inert soybean oil in the form of calcium salts of fatty acids (CSFA) can supply ruminants with lipids, with minimal effects on ruminal fermentation and fiber digestibility. However, there is a shortage of information on the effect of CSFA on characteristics of rumen fermentation in grassland goats. Thus, the present study aimed to assess the addition of CSFA to concentrate on the parameters of rumen fermentation of grazing goats. Five rumen cannulated crossbreed Boer x Saanen goats (71.4 + 11.8 kg) were distributed in a Latin square 5x5 design with five treatments (0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA). Each experimental period lasted 21 days, including 14 days for adaptation and seven days for data collection. Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and CSFA derived from soybean oil at five levels of inclusion. For grazing goats, an area with Stargrass (*Cynodon nlemfuensis*) was used. Dry matter intake and digestibility were estimated by the concentration of *n*-alkanes in the forage and feces; these included naturally present C_{31} and C_{33} and the orally administered homologue C_{32}. The pH, ammonia N and volatile fatty acids (VFA) content of the rumen were analyzed in the ruminal fluid that was sampled on 21 day of the experimental period at 0, 2, 4, 6 and 8 hours after concentrate supplementation. There was no effect on the intake and digestibility coefficients of dry matter and nutrients for goats fed with the concentrate containing CSFA. Nevertheless, the ether extract intake and digestibility coefficient showed a positive linear effect. CSFA can influence rumen fermentation in grazing goats. The pH and ammonia N concentration in the rumen showed a linear effect with the addition of CSFA. There was no effect observed for the volatile fatty acid molar concentration in the rumen fluid after grazing goats were fed with the experimental diet. In conclusion, further research is needed to investigate the addition of CSFA to goat diets because there is evidence that CSFA increases ruminal pH and decreases excess ruminal ammonia without changing the volatile fatty acid concentration in the rumen fluid.

Keywords: ammoniac nitrogen, digestibility, fat supplementation, *n*-alkanes, volatile fatty acids

1. Introduction

In general, a strategy to increase the concentrate energy content in order to improve the performance of lactating animals is to add to the diet foods that are rich in lipids, such as oilseed grains and/or oil (cottonseed, soybean, sunflower, linseed, etc.). According to Palmquist (1994), several factors affect this management practice, such as the commercial availability of high quality lipids, increased energy intake when dry matter intake is reduced and the replacement of carbohydrates by lipids to improve grass intake and ruminal fermentation. In addition, lipids improve fat-soluble vitamin absorption, supply fatty acids to the membranes of tissues, act as precursors of metabolic pathways and increase certain fatty acids in milk fat, especially polyunsaturated fatty acids (Palmquist and Mattos, 2011). However, depending on the amount supplied, the degree of unsaturation and the degree of rumen-protected lipid, reduced performance can occur owing to the decreased activity of cellulolytic microorganisms, with a consequent reduction in fiber digestibly (Yang et al., 2009; Palmquist and Mattos, 2011).

The saponification of long chain fatty acids, typically derived from soybean or palm oils, with calcium ions results in calcium salts, a type of rumen-inert fat containing high levels of fatty acids such as palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1) and linoleic acid (18:2); this was originally proposed by Jenkins and Palmquist (1982). Thus, feeding calcium salts of fatty acids (CSFA), which are inert in the rumen, can enhance the energy density of rations and has no negative effects on ruminal fermentation.

CSFA is a complex of calcium ions with long chain fatty acids; the main sources are soybean oil or palm oil, depending on the commercial product. CSFA is inert in the rumen and is dissociated in the acidic conditions of the abomasum. Among the benefits of CSFA are the possibility of increasing the energy content of the diet without influencing fiber digestibility, allowing high levels of inclusion in ruminant diets. In this sense, CSFA are interesting, because they do not change ruminal fermentation (Sirohi et al., 2010). Thus, CSFA is an energy supplement which in combination with other foods can increase dry matter intake, therefore providing good availability of nutrients for satisfactory yields.

The evaluation of a food for ruminants should include the rumen fermentation conditions, which are indicative of the potential of the food in question to promote better performance. However, there is a shortage of information on the effect of CSFA

on rumen fermentation in goats in a grassland system. Thus, this study aimed to evaluate the addition of CSFA to concentrate fed to grassland goats on the nutritive value of the diet and rumen fermentation.

2. Material and methods

2.1. Goats and experimental treatments

The experiment was conducted at an experimental farm at the State University of Maringá, southern Brazil. Five dry empty Boer+Saanen goats with a ruminal cannula and an average body weight 71.4 ± 11.8 kg were distributed in a Latin square design with an experimental period of 21 days, of which 14 days were for adaptation and seven days were for data collection. The Latin square design was 5x5 with five treatments (0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA).

Pelleted concentrate was composed of ground corn, soybean meal, a mineral-vitamin supplement for goats, salt and rumen-inert fat in the form of CSFA from a commercially available product derived from soybean oil (Lactoplus® from Dalquim Chemical Industry Ltd., with 1.94 $g.g^{-1}$ total digestible nutrients, 820 $g.kg^{-1}$ ether extract, 100 $g.kg^{-1}$ calcium, 260 $g.kg^{-1}$ oleic acid and 420 $g.kg^{-1}$ linoleic acid); in five levels of inclusion (0%, 1.5%, 3.0%, 4.5% and 6.0% of the concentrate) (Table 1). The among of concentrate offered to the goats was established at 1 $kg.day^{-1}$ as feed, i.e. half of the estimated nutritional requirements of Saanen goats (NRC, 2007) with a body weight of 60 kg and a milk yield of 3.0 $kg.day^{-1}$ with 3.5% fat.

Goats remained in the pasture for approximately seven hours (8:00 am to 3:30 pm) and were housed in single pens for the rest of the day and overnight, where they received the pelleted concentrate. The goats had free access to water in the pasture and pens.

From day 10 to 19, a cellulose capsule of synthetic paired chain *n*-alkane ($C_{32}H_{66}$, Dotriacontane, 97% purity, ref. D223107, Sigma-Aldrich Corp., St Louis, MO, USA) was inserted into the rumen by an oral probe twice daily at 8:00 am and 4:00 pm, supplying a total of 80 mg of $C_{32}H_{66}$/day.

For grazing goats, an area of one hectare (1 ha) was used with Stargrass (*Cynodon nlemfuensis*) maintained by continuous stocking (Table 2). The grassland was fertilized and corrected through physical and chemical analysis of the soil and grass demand. Fertilizer was applied at an N-P-K ratio of 8 $kg.ha^{-1}$ nitrogen, 67 $kg.ha^{-1}$ phosphorus and

70 kg.ha^{-1} potassium (200 kg of N-P-K fertilizer 4-20-20; 150 kg of single superphosphate and 50 kg of potassium chloride) in September 2011. The grazing period was from June 17 2012 to September 24 2012.

2.2 Samples collection and analyses

Sampling of the forage for chemical analysis and manual separation of morphological components (leaf blades, stems and sheaths, dead material), were collected once in each experimental period; to ensure random sampling, one 1.0 m² wire square was thrown eight times in the paddock and the grass was cut 15 cm above the ground. Samples of forage to determine total forage mass were cut close to the soil. The sward height was measured with a wooden ruler graduated in centimeters at 20 random points. For chemical analysis, samples of concentrate were taken during each experimental period and pooled.

Fecal grab samples were taken twice daily at 8:00 am and 4:00 pm from day 15 to 20 and a portion (about 30 g) was dried for 72 h at 55°C and composited by goat within period for later chemical analysis.

Samples of forage and feces from each period were oven-dried (55°C for 72 h), then ground through a 1-mm screen in a Wiley mill. The concentrate was ground through a 1-mm screen in a hammer mill. Dry matter was determined according to method no. 934.01 of AOAC (1998). Ash was determined by combustion in a muffle furnace according to method no. 942.05 (AOAC, 1998). Calcium and phosphorus were analyzed by using acid digestion with nitric and perchloric acid (1:2). After that, they were filtered to obtain a mineral solution. Calcium and phosphorus readings were obtained by using atomic absorption (spectrophotometer GBC 932 AA in flame air-acetylene) and colorimetric (spectrophotometer Shimadzu UV-1601 UV-Visible Spectrophotometer®), respectively, according to (AOAC, 1990). Total nitrogen (TN) was evaluated using a Tecnal TE-036/1 (Tecnal, Piracicaba, São Paulo, Brazil) following AOAC method no. 988.05 (1998) and crude protein (CP) was estimated as TN x 6.25. The ether extract (EE) was assessed using a Tecnal TE-044/1 apparatus according to method no. 920.39 (AOAC, 1998). Neutral detergent fiber (NDF) was evaluated as described by Van Soest et al. (1991) without the use of sodium sulfite and with the inclusion of heat-stable α-amylase (Alpha-amylase Termamyl 2x, Tecnoglobo®, Curitiba, Brazil). Total carbohydrates (TC) and total digestible nutrient (TDN) were estimated according to the equations described by Sniffen et al. (1992): TC

($g.kg^{-1}$ of DM) = 1000 - (CP + EE + ash) and TDN = dCP + (2.25 × dEE) + dTC, in which dCP = digestible crude protein, dEE = digestible ether extract and dTC = digestible total carbohydrates. The method used to calculate the feed energy value ($Mcal.kg^{-1}$) using the digestible energy (DE) and metabolizable energy (ME) was done using the following equation (NRC, 2007): DE = 0.04409 × TDN(%); ME = 1.01 × DE - 0.45.

On day 21, ruminal fluid was collected manually from different locations within the rumen at 0, 2, 4, 6 h and 8 h after concentrate supplementation. Rumen pH was measured immediately after sample collection with a portable pH meter (Tecnal, Piracicaba, SP, Brazil). After that, the rumen fluid was then strained through four layers of cheesecloth and two aliquots of strained ruminal fluid were collected.

To determine the ammonia nitrogen concentration ($N\text{-}NH_3$), the samples were acidified with 2 mL of sulfuric acid 1:1 in 100 mL of each sample and frozen for later determination by the potassium hydroxide (KOH) distillation method described by Preston (1995).

To determine the volatile fatty acid (VFA) concentration, the samples were frozen for later determination. Next, samples of ruminal fluid were centrifuged for 15 min at 3,500 rpm at 4°C and 2 mL of rumen fluid centrifugate was acidified with 0.4 mL of formic acid (88%). VFA analyses were performed according to Palmquist and Conrad (1971) at 0 and 4 h after concentrate supplementation.

A gas chromatograph (SHIMADZU, GC-2014®) equipped with an autoinjector SHIMADZU, AOC - 20i®) was used to quantify the VFA. The column used was a 19091N, HP-INNOWax GC Column (Agilent Technologies®, 30 m x 0.32 mm x 0.50 μm). The carrier gas was nitrogen at a constant flux of 3.18 mL/min. Temperature gradients were controlled for the injector (200ºC) and the column (80ºC for 3 min and 20ºC/min to 240ºC). The GC detector temperature was set to 250ºC. With a microliter syringe, 1 μL of the sample was injected with a split ratio of 1:10.

2.3 Extraction, identification and quantification of n-alkanes

The extraction and determination of the n-alkane content in forage and feces were determined according to the method of Mayes et al. (1986) modified by Vulich et al. (1995) based on the direct saponification of samples.

A gas chromatograph (GC Agilent 7890A®) equipped with a mass selective detector (MS Agilent 5975C®) was used to identify and quantify the *n*-alkanes. The

column used was a Zebron™ ZB-5MS (30 m x 0.32 mm x 0.25 μm, absorbent composed of 5% phenyl-arylene-95% polydimethylsiloxane). The carrier gas was H_2 at a constant flux of 1 mL/min. Temperature gradients were controlled for the injector (300ºC) and the column (130ºC for 1 min, 10ºC/min to 210ºC and 5ºC/min to 310ºC with a hold of 1 min; 32 min). The MS source temperature was set at 250ºC and the temperature of the MS quadrupole was 120°C. With a microliter syringe, 1 μL of the sample was injected with a split ratio of 1:10.

The gas chromatograph process was calibrated with an external standard solution of a synthetic n-alkane mix including C_{24}, C_{26}, C_{28}, C_{32}, C_{34} and C_{36} (Tetracosane by 99% purity ref. no. T8752, Hexacosane by 99% purity ref n no. 241687, Dotriacontane by 97% purity ref. no. D223107, Tetratriacontane by 98% purity ref. no. 287261, Hexatriacontane by 98% purity ref. no. 52919; Sigma-Aldrich Corp., St Louis, MO, USA). The chromatography peak areas corresponding to each n-alkane were determined by MSD ChemStation Data Analysis®. The identified peaks were converted to the n-alkane quantity in reference to each peak area and the internal standard C_{34}, then calculated into $mg.g^{-1}$ of DM.

The dry matter intake (DMI) was estimated by the n-alkane concentration in forage and feces naturally present in the diet (C_{31} and C_{33}) and the homologue C_{32}, which was orally administered. The estimated values of DMI with the pairs C_{31}:C_{32} and C_{33}:C_{32} were obtained by the Mayes et al. (1986) equation: $DMI = [(F_i/F_p)*D_p]/[H_i-(Fi/F_p)*H_p]*100$; where: DMI = dry matter intake ($kg\ MS.day^{-1}$); F_i = *n*-alkane of unpaired chain (C_{31} or C_{33}) content ($mg.kg^{-1}$ MS) in feces; F_p = *n*-alkane of paired chain (C_{32}) content in feces; D_p = quantity (mg) of synthetic *n*-alkane of paired chain (C_{32}) fed; H_i = natural *n*-alkane of unpaired chain (C_{31} or C_{33}) content in forage, H_p = natural *n*-alkane of paired chain (C_{32}) in forage. The DM digestibility was estimated by the equation: DMD = 1-(ID/IF) x 100; where: DMD = dry matter digestibility coefficient by n-alkane, ID = internal content of n-alkane in forage, and IF = internal content of *n*-alkane in feces.

2.4. Statistical Analysis

The data were analyzed by analysis of variance, linear curve estimation and the quadratic of the regression equations ($\alpha = 0.05$), with the general model: $Y_{ijkl} = \mu + T_i + P_j + A_l + e_{ij}$ where: Y_{ijkl} = the dependent variable, μ = general constant; D_i = effect of concentrate diet *i*; P_j= effect of period *j*; Al = effect of animal *l*; e_{ijkl} = random error.

The critical points of the quadratic equations ($Y = c + bx + ax^2$) were found using the definition of the derivative, where $X = -b/(2 \times a)$, and $Y = -(b^2)/(4 \times a)$.

3. Results

There was no significant effect on the intake of dry matter, organic matter, crude protein, neutral detergent fiber, total carbohydrates and total digestible nutrients in goats fed the concentrate with CSFA after grazing. However, the ether extract intake was linearly increased with the addition of CSFA in the concentrate. The digestibility coefficients of dry matter, organic matter, neutral detergent fiber, total carbohydrates and non-fiber carbohydrates were not changed by the treatments. However, the significant effect of the ether extract digestibility coefficients did not enhance the energy values of diets, including total digestible nutrients, digestible energy, metabolizable energy and net energy for lactation (Table 3).

The pH and ammonia N concentration in the rumen fluid showed a linear effect with CSFA addition (Table 4 and Figure 1). However, according to the quadratic equations for pH and ammonia N as a function of time after feeding with each concentrate (Table 5 and 6), the lowest pH value of the rumen fluid was 5.5 and occurred at 5 h 33 min after feeding with the 1.5%concentrate, and for ammonia N, the maximum value was 37.05 mg.dL-1 4 h 27 min after feeding with the 1.5% concentrate. The peak ammonia concentration occurred between 3 h 39 min and 4 h 27 min after concentrate feeding.

No effect was observed for total volatile fatty acids, the molar concentrations of acetate, propionate, butyrate, isobutyrate, valerate, isovalerate or the acetate:propionate ratio in rumen fluid zero hours and four hours after feeding with the experimental concentrate (Table 7 and Figure 2). However, the values observed four hours after feeding with the concentrate were 69% higher than those observed at zero hours.

The average values observed for the concentration (mmol.L-1) of volatile fatty acids (VFA) in ruminal fluid before feeding with the concentrate were 61.88 total VFA, 42.11 acetate, 10.39 propionate, 6.82 butyrate, 0.62 isobutyrate, 0.78 valerate, 1.16 isovalerate and 3.81 for the acetate:propionate ratio. Four hours after feeding with the concentrate, the average values were 108.93 total VFA, 66.48 acetate, 25.00 propionate, 13.89 butyrate, 0.58 isobutyrate, 1.60 valerate, 1.39 isovalerate and 2.79 for the acetate:propionate ratio.

4. Discussion

The dry matter and nutrient intake were not modified by the addition of CSFA to the concentrate for goats grazing in a Stargrass pasture, which was 1.81 kg.day-1 for DMI. Molina (2013) also showed 2.0 kg.day-1 for the DMI of Saanen goats fed with 0, 6.25, 12.50, 18.75 and 25.00 g.kg-1 of CSFA. When compared to other studies, in which the goats were raised on grassland systems, the results are in agreement. Rufino et al. (2012) supplemented with 1.5% of body weight in Anglo-Nubian goats grazed on a Tanzania-grass grassland and showed 1.89 kg.day-1 for DMI. Mancilla-Leytón et al. (2013) observed 1.87 kg.day-1 for DMI when goats were supplemented with 0.5 kg.day-1 of concentrate in scrublands (158.8 g.kg-1 CP and 579.4 g.kg-1 NDF).

The mean dry matter digestibly (DMD) in this study for goats was 0.64 g.g-1. Silva et al. (2007) and Molina (2013) showed values of 0.63 g.g-1 and 0.65 g.g-1, respectively. Higher values were found by Sanz Sampelayo et al. (2002) who showed a mean DMD of 0.69 g.g-1 and Souza et al. (2014) who showed a mean DMD value of 0.70 g.g-1.

The linear positive effect on ether extract intake (EEI) for goats fed with the concentrate containing CSFA is explained by the ether extract (EE) content in the concentrate (Table 1). The addition of 15 grams of CSFA to the concentrates increases the content of EE by 11.9 g.kg-1. This same effect, i.e. linear positive, was observed for the ether extract digestibility coefficient. This effect may be associated with the higher concentration of unsaturated fatty acids in CSFA available in the intestine, which have higher solubility in micelles, and thus are more digestible compared to fatty acids with a higher degree of saturation (Palmquist and Mattos, 2011).

The addition of CSFA to concentrate rations for grazing goats changed the neutral detergent fiber digestibility (NDFD); however, this result shows that forms of rumen-inert lipids cannot decrease cell wall digestibility, supported by studies by Molina (2013), Sanz Sampelayo et al. (2002) and Souza et al. (2014).

The rumen pH was linearly increased with CSFA inclusion in the goat diet. Although the optimal pH range (pH 6.2 to 7.0) was not maintained, CSFA addition may be a strategy for goat diet substitution rather than starch, as it does not negatively influence rumen pH.

Although the low pH rumen observed (5.83 to 6.0) in all treatments was not appropriate for cellulolytic microorganisms, its fixatio n in the fiber portion of food was not inhibited. According to Van Soest (1994), low pH (inferior to 6.2) is a factor that

may reduce cellular division and cellulolytic bacterial growth, which would lead to cellular wall degradation. However, in this study, the low pH values did not reduce the neutral detergent fiber digestibility, which can be explained due to due to the period that the ruminal pH remained below 6.2. This low pH is was explained by the concentrate ratio in the diet, which was 51%, and also by the time at which rumen fluid samples were collected, i.e. after concentrate ration feeding.

The negative linear response of ruminal ammonia nitrogen (N-NH3) explains 92% (r2 = 0.92) of the results, which ranged between 27.1 to 32.0 mg.dL-1. According to Doreau and Ferlay (1995), this reduction in the N-NH3 content in the rumen is one of the major characteristics of ruminal defaunation. In addition, these results may be related to the relationship between protein and available energy for ruminal fermentation, as 23.5 mg.dL-1 of N-NH3 is necessary for the maximum ruminal fermentation rate (Mehrez et al., 1977).

Lana et al. (2007) supplemented goats with soybean oil at levels of 0, 1.5, 3.0, 4.5, 6.0 and 7.5% of diet dry matter and observed inferior values (15.77 mg.dL-1 N-NH3) compared to our study. However, Silva et al. (2007) observed 31.06 mg.dL-1 of ruminal N-NH3 by adding 5% CSFA to goat diets. The values of this study are probably related to the diet composition, which affected N-NH3 availability in the rumen, and also to the high concentrate content in the diets needed to provide 50% of goat requirements, thus increasing the action of microorganisms and consequently the ammoniac nitrogen values in the rumen. Consequently, the relationship between protein and available energy for ruminal fermentation changed, as microorganism are unable to use fat as a source of energy for growth (Arcuri et al., 2011). The high ammonia value in rumen can be associated with a decrease in the efficiency of nitrogen utilization to synthetize microbial proteins. According to Rapetti and Bava (2008), in a situation where energy is a limiting factor, an increase in amino acid deamination by microorganisms can occur in the rumen as the bacteria subsequently ferment the carbon skeletons as a source of energy.

The pH curve presented an inverse pattern to the ammonia content, in agreement with Lana et al. (2005) and Lana et al. (2007) in which goats received oil soybean and propolis extract in the diet. The lowest pH values occurred at 6 h 30 min after feeding, whereas the highest value of ammonia occurred 4 h after feeding with the concentrate, which suggests fast activity of fermenter bacteria with the concentrate.

It was observed that there were differences in the concentrations of VFA as a function of time (0 h and 4 h); 4 hours after feeding with the concentrate, the total VFA production increased due to an increase in propionate, butyrate and valerate. However, acetate production was decreased due to impaired production by cellulolytic bacteria, whose ruminal population was decreased owing to the high amount of concentrate in the diet. Li et al. (2014) assessed the effects of dietary effective fiber on rumen degradable starch ratios and rumen fermentation in dairy goats receiving diets with a forage to concentrate ratio of 50:50; these authors reported 64.4 mol.100 mol-1 of acetate and 18.2 mol.100 mol-1 of propionate, values similar to those observed in this study.

Data in literature reports variable results on the effect of supplementation with CSFA on rumen VFA production in ruminants. For example, Grummer (1988) reported that ruminal pH, total VFA, and the molar concentrations of acetate and propionate were not affected by fat supplementation with calcium salts of palm oil fatty acids (680 g.day-1) or prilled fat (680 or 910 g.day-1) for Holstein cows fed a basal diet containing 45% concentrate, 27.5% alfalfa silage and 27.5% corn silage (DM basis). Cenkvári et al. (2005) reported that when sheep were fed a diet composed of alfalfa hay and concentrate and supplemented with 75 g.day-1 of calcium salts of linseed oil (5.4% of dry matter), the total VFA concentration in the rumen fluid measured 3 h after feeding did not change, the acetate:propionate ratio decreased and the butyrate and valerate levels increased. Shibata et al. (2011) reported that fed cows with 400 g.day-1 of CSFA had decreased total VFA 2 h after feeding with CSFA.

However, in the present study, no changes in the molar concentration and proportion of VFA in the rumen fluid were observed. This may indicate that CSFA from soybean oil do not influence ruminal fermentation. This can be explained by the CSFA level, i.e. 0%, 1.5%, 3.0%, 4.5% and 6.0% CSFA in the concentrate delivered EE at approximately 2.37%, 2.86%, 3.20%, 3.67% and 4.37% of the DM content in the daily rations; the ether extract level may not have been sufficient to significantly alter rumen fermentation.

It is possible that microbial protein synthesis can by reduced at higher levels of CSFA and when the relationship between protein and the energy available to rumen fermentation are not balanced. Souza et al. (2014) reported a decrease in the levels of milk protein in Saanen goats with the addition of CSFA (0%, 2.87%, 5.46% or 8.05% of the diet) and attributed this effect to a reduction in microbial protein synthesis because, according to Santos and Pedroso (2011), microbial protein is the main source of

metabolizable protein in ruminants, with a balanced amino acid profile in relation to milk protein.

5. Conclusion

The addition of CSFA to goat concentrate did not influence dry matter and nutrient intake; however, CSFA influenced the rumen fermentation of goats grazing on Stargrass. Further research is suggested with the addition of CSFA to goat diets, because there is evidence that supplying CSFA increases ruminal pH and decreases excess ruminal ammonia without changing the volatile fatty acid concentration in the rumen fluid after grazing goats are fed with the experimental diet.

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Table 1
Ingredients and chemical composition of the concentrate

	Level of calcium salts of fatty acids[1]				
Composition	0.0%	1.5%	3.0%	4.5%	6.0%
Ingredient (g.kg^{-1} DM)					
Ground corn	695.0	676.0	658.0	639.0	621.0
Soybean meal	280.0	284.0	287.0	291.0	294.0
Rumen bypass fat[1]		15.0	30.0	45.0	60.0
Mineral-vitamin supplement[2]	20.0	20.0	20.0	20.0	20.0
Salt	5.0	5.0	5.0	5.0	5.0
Chemical (g.kg^{-1} DM)					
Dry matter (g.kg^{-1})	911.5	915.6	919.8	923.8	908.7
Organic matter	961.3	957.3	961.4	952.5	950.7
Ash	38.7	42.7	38.6	47.5	49.3
Crude protein	214.7	212.8	209.6	213.7	223.9
Ether extract[4]	25.02	36.91	48.82	60.71	72.61
Neutral detergent fibre	103.60	94.04	97.55	89.34	86.92
Non-fibre carbohydrates	617.9	613.6	605.4	588.7	567.3
Total carbohydrates	721.53	707.66	702.90	678.02	654.23

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Product commercial Lactoplus®, chemical composition: 3.39 Mcal.kg^{-1} of metabolisable energy, 820 g.kg^{-1}fat, 100 g.kg^{-1} Ca.
[3]Chemical composition (per kg of Caprinofós® with mineral organic): Ca 240 g; P 71 g; F 710 mg (Max); Mg 20 g; K 28.2 g; S 20 g S; Fe 250 mg; Cu 400 mg; Mn 1,350 mg; Zn 1,700 mg; Co 30 mg; I 40 mg; Se 15 mg; Cr 10 mg; Vitamin A 135,000 UI; Vitamin D3 68,000 UI; Vitamin E 450 UI.
[4]From the result of the chemical composition of foods (ground corn and soybean meal) and the composition of the Lactoplus® label.

Table 2
Chemical composition and forage mass in Stargrass (*Cynodon nlemfuensis*) of the each experimental period

	Period[1]				
	P1	P2	P3	P4	P5
Chemical ($g.kg^{-1}$ DM)					
Dry matter (g.kg-1)	306.3	312.9	370.5	451.8	391.3
Organic matter	944.9	940.5	923.6	937.4	936.4
Ash	55.1	59.5	76.4	62.6	63.6
Crude protein	149.8	152.4	154.7	94.6	102.3
Ether extract	22.3	18.7	15.7	17.6	14.0
Neutral detergent fibre	735.7	674.6	680.2	690.6	694.4
Non-fibre carbohydrates	37.1	94.9	73.0	134.6	125.6
Total carbohydrates	772.8	769.5	753.1	825.2	820.1
Sward height (cm)	54.8	49.7	44.05	38.95	34.75
Forage mass ($kg.DM.ha^{-1}$)					
Forage mass	4273.0	4068.1	3860.2	3448.3	3330.6
Forage mass (above 0.15 meters)	1482.3	986.2	1506.2	1457.8	958.2
Leaf blade	534.8	266.5	442.0	444.5	323.2
Stem and sheath	737.9	369.9	522.8	593.4	306.8
Leaf: Stem ratio	0.72	0.72	0.85	0.75	1.05

[1]Sampling days: P1: 18 June 2012, P2: 8 July 2012, P3: 28 July 2012, P4: 19 August 2012, P5: 6 September 2012.

Table 3
Dry matter and nutrients intake and total apparent digestibility of goats in grassland fed by experimental diets

	Level of calcium salts of fatty acids[1]						
	0.0%	1.5%	3.0%	4.5%	6.0%	SE	P-value
Dry matter intake ($kg.day^{-1}$)							
Total DMI	1.69	1.75	1.87	1.91	1.83	0.06	0.12
Forage DMI	0.77	0.83	0.95	0.98	0.92	0.06	0.14
Concentrate DMI	0.92	0.92	0.92	0.93	0.91		
Total DMI ($g.kg^{-1}$ of $BW^{0.75}$)	69.34	74.30	75.63	79.19	77.15	3.75	0.45
Nutrient intake ($kg.day^{-1}$)							
Organic matter	1.60	1.66	1.77	1.80	1.73	0.06	0.13
Crude protein	0.30	0.30	0.32	0.33	0.32	0.01	0.08
Ether extract	0.04	0.05	0.06	0.07	0.08	0.00	<0.00[a]
Neutral detergent fibre	0.63	0.66	0.75	0.77	0.72	0.04	0.18
Total carbohydrates	1.27	1.30	1.40	1.40	1.33	0.05	0.26
Non-fibre carbohydrates	0.64	0.64	0.65	0.64	0.63	0.01	0.10
Total digestible nutrients	1.04	1.20	1.22	1.30	1.17	0.06	0.09
Digestibility coefficient ($g.g^{-1}$)							
Dry matter	0.60	0.69	0.64	0.67	0.62	0.03	0.22
Organic matter	0.64	0.72	0.68	0.71	0.67	0.02	0.23
Crude protein	0.55	0.66	0.60	0.66	0.60	0.03	0.14
Ether extract	0.50	0.67	0.70	0.78	0.78	0.04	<0.00[b]
Neutral detergent fibre	0.50	0.60	0.58	0.62	0.57	0.04	0.29
Total carbohydrates	0.67	0.73	0.70	0.72	0.68	0.02	0.30
Non-fibre carbohydrates	0.83	0.83	0.84	0.83	0.80	0.01	0.12
Energy values of diets ($Mcal.kg^{-1}$)							
Total digestible nutrients ($g.g^{-1}$)	0.62	0.69	0.65	0.68	0.66	0.02	0.24
Digestible energy[2]	2.72	3.02	2.88	2.99	2.82	0.10	0.24
Metabolizable energy[2]	2.29	2.60	2.45	2.57	2.40	0.10	0.24

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[2]Estimated by NRC (2007) equations.
[a]$Y = 0.04 + 0.008x$, $r^2 = 0.99$.
[b]$Y = 0.55 + 0.044x$, $r^2 = 0.99$.

Table 4
Rumen fermentation characteristics after grazing and concentrate feeding (0 to 8 hours) of goats in grassland fed by experimental diets

	Level of calcium salts of fatty acids[1]					SE	*P*-value
	0.0%	1.5%	3.0%	4.5%	6.0%		
pH	5.79	5.74	6.11	5.95	5.97	0.04	<0.01[a]
Amonia N ($mg.dL^{-1}$)	30.75	32.02	32.19	27.08	28.28	1.04	<0.01[b]

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.
[a] Regretion equation: $Y = 5.81+0.03x$. $r^2 = 0.56$.
[b] Regretion equation: $Y = 32.04-0.66x$. $r^2 = 0.48$

Table 5
Regression equations and critical point obtained for pH in function of time after fed for each concentrate

Concentrate[1]	Regretion equation ; r^2	min. pH	Time (hours)
0.0%	$Y = 6.23 - 0.22x + 0.02x^2$; $r^2 = 0.94$	5.63	5h50
1.5%	$Y = 6.40 - 0.32x + 0.03x^2$; $r^2 = 0.99$	5.55	5h33
3.0%	$Y = 6.51 - 0.25x + 0.02x^2$; $r^2 = 0.99$	5.73	6h25
4.5%	$Y = 6.53 - 0.30x + 0.03x^2$; $r^2 = 0.98$	5.78	5h00
6.0%	$Y = 6.38 - 0.21x + 0.02x^2$; $r^2 = 0.93$	5.83	5h25

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

Table 6
Regression equations and critical point obtained for ammonia N in function of time after fed with concentrate

Concentrate[1]	Regretion equation ; r^2	max. Amonia N	Time (hours)
0.0%	$Y = 27.39 + 4.46x - 0.60\ x^2$; $r^2 = 0.96$	35.68	3h72
1.5%	$Y = 25.56 + 5.38x - 0.63\ x^2$; $r^2 = 0.93$	37.05	4h27
3.0%	$Y = 27.12 + 4.22x - 0.49\ x^2$; $r^2 = 0.96$	36.21	4h31
4.5%	$Y = 21.93 + 4.43x - 0.52\ x^2$; $r^2 = 0.96$	31.37	4h26
6.0%	$Y = 26.44 + 3.93x - 0.58\ x^2$; $r^2 = 0.67$	33.10	3h39

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

Table 7
Volatile fatty acids (VFA) concentration (mmol.L^{-1}) and proportions (mol.100 mol^{-1}) in rumen fluid after grazing of goats fed by experimental diets

	Level of calcium salts of fatty acids[1]						
	0.0%	1.5%	3.0%	4.5%	6.0%	SE	*P*-value
Before fed with concentrate							
Total VFA (mmol.L^{-1})	59.32	64.79	62.47	59.13	63.71	5.04	0.90
Acetate	38.97	45.36	41.93	40.56	43.74	3.97	0.80
Propionate	10.08	10.64	10.60	10.02	10.63	1.01	0.98
Butyrate	7.18	6.43	7.34	6.24	6.91	0.64	0.71
Isobutyrate	0.59	0.60	0.64	0.62	0.65	0.10	0.99
Valerate	1.37	0.66	0.68	0.59	0.58	0.28	0.28
Isovalerate	1.14	1.10	1.27	1.10	1.20	0.18	0.96
VFA (mol.100 mol^{-1})							
Acetate	63.76	69.92	67.02	68.07	68.15	1.71	0.20
Propionate	16.69	16.13	17.21	16.84	16.95	1.01	0.96
Butyrate	13.39	10.13	11.52	10.97	11.01	1.27	0.49
Isobutyrate	1.00	0.97	1.06	1.10	1.04	0.13	0.96
Valerate	3.15	1.06	1.11	1.05	0.93	0.88	0.38
Isovalerate	2.02	1.80	2.08	1.97	1.92	0.24	0.94
Acetate:propionate	3.81	4.43	3.98	4.05	4.09	0.29	0.66
4 hours after fed with concentrate							
Total VFA (mmol.L^{-1})	99.50	110.10	113.47	111.65	109.94	10.31	0.88
Acetate	59.21	66.29	70.21	69.98	66.70	5.64	0.66
Propionate	23.03	25.49	25.04	25.16	26.26	3.54	0.97
Butyrate	13.37	14.81	14.48	13.32	13.46	2.00	0.97
Isobutyrate	0.54	0.54	0.64	0.56	0.63	0.11	0.92
Valerate	2.08	1.49	1.58	1.39	1.46	0.28	0.46
Isovalerate	1.27	1.49	1.52	1.24	1.43	0.24	0.88
VFA (mol.100 mol^{-1})							
Acetate	56.00	60.06	62.11	63.13	61.09	2.76	0.44
Propionate	21.86	22.84	22.59	22.30	23.63	2.06	0.98
Butyrate	16.96	13.58	12.11	11.73	12.13	2.59	0.61
Isobutyrate	0.54	0.56	0.53	0.50	0.57	0.08	0.99
Valerate	3.33	1.40	1.39	1.24	1.30	0.81	0.35
Isovalerate	1.31	1.57	1.28	1.10	1.28	0.21	0.64
Acetate:propionate	2.64	2.75	2.85	2.96	2.73	0.30	0.95

[1]Level of calcium salts of fatty acids derived of soybean oil addition on concentrate.

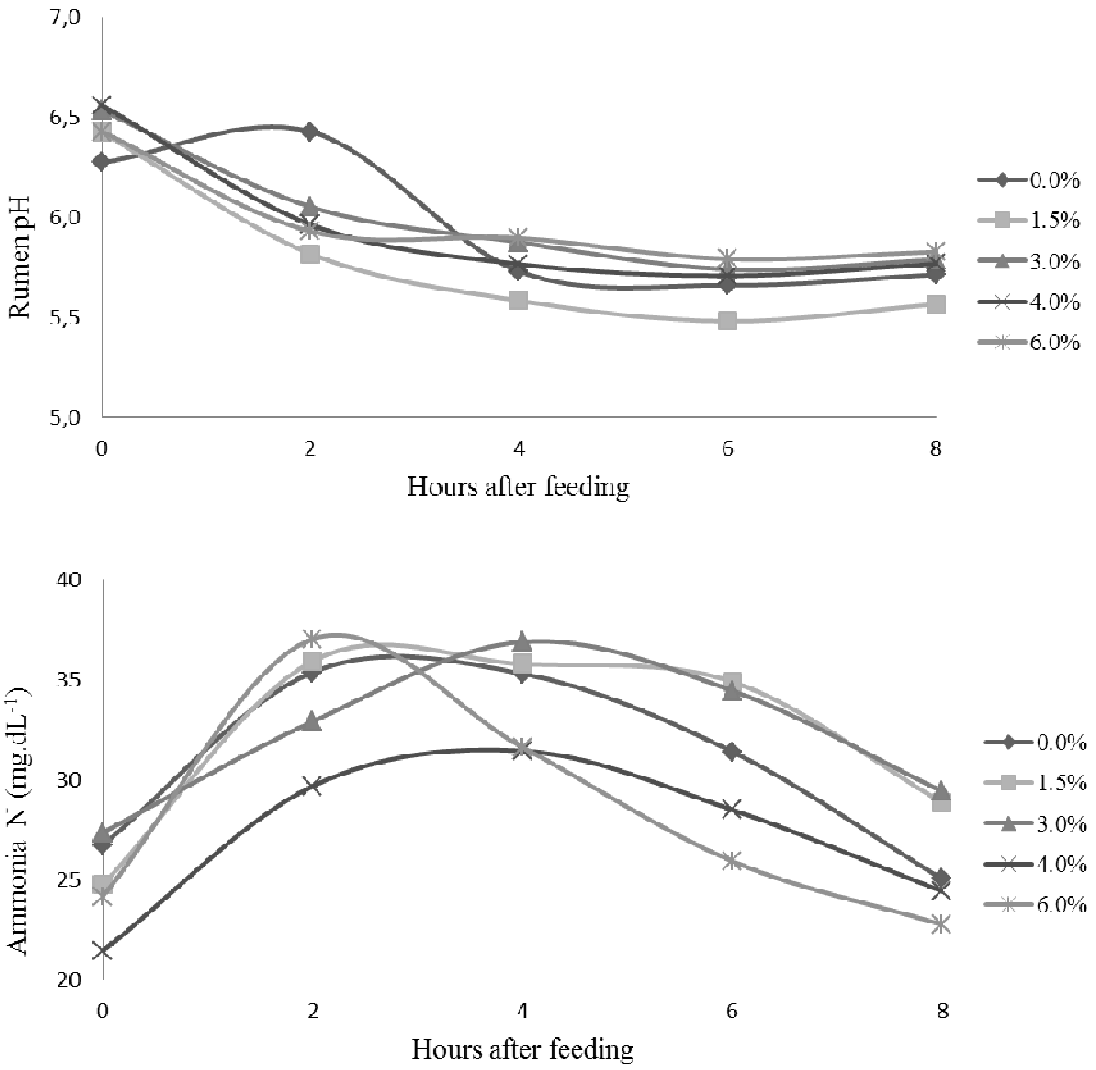

Figure 1
Ammonia nitrogen and pH curves in rumen fluid after grazing and in function of time after fed for each concentrate containing calcium salts of fatty acids derived of soybean oil

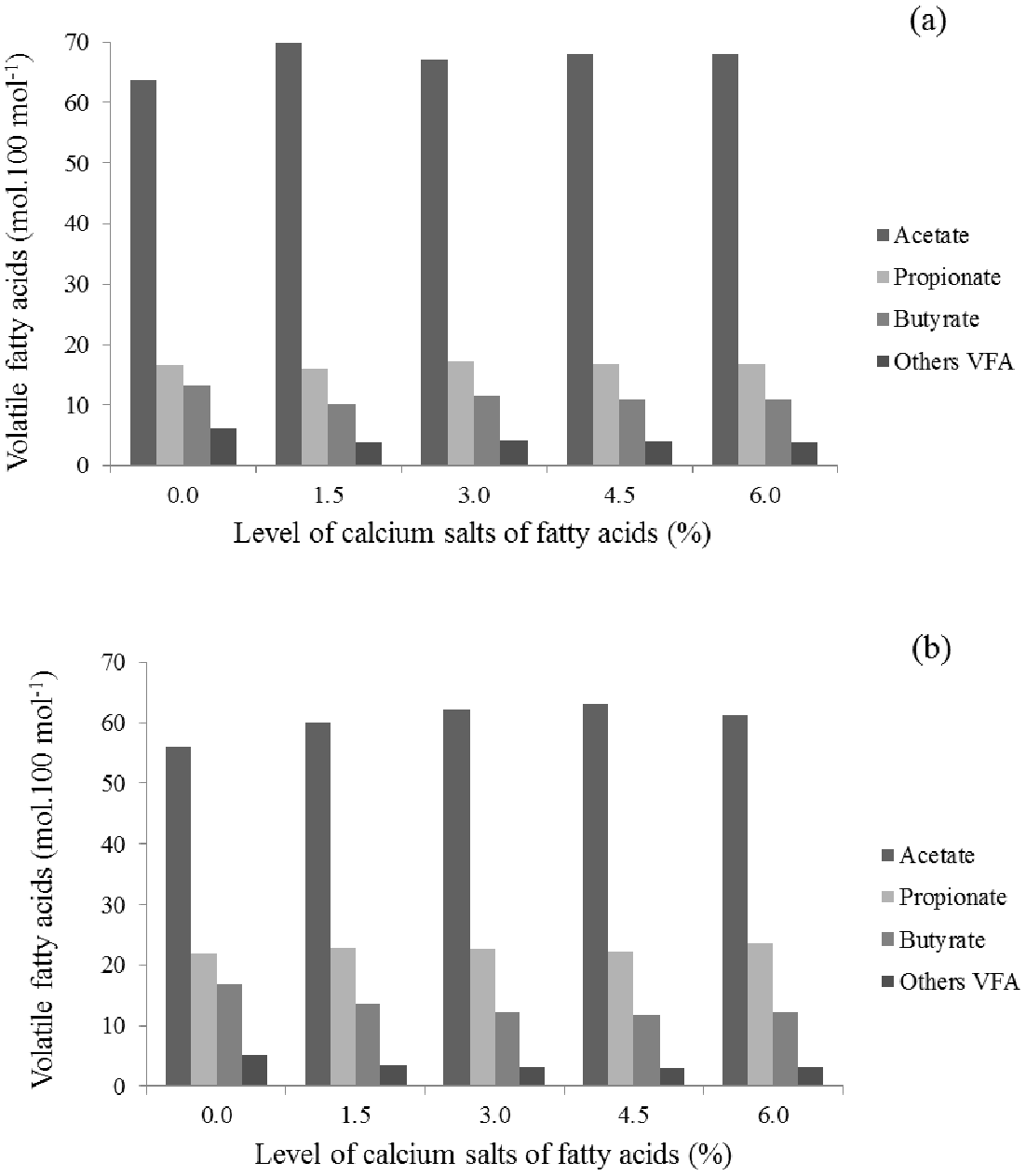

Figure 2
Volatile fatty acid proportion in rumen fluid after grazing of goats in grassland fed by experimental diets. (a) before fed with concentrate; (b) 4 hours after fed with concentrate.

IX - CONSIDERAÇÕES FINAIS

Na PARTE I da Tese, foi apresentada uma aboradagem capaz de identificar e analisar a diversidade de sistemas de produção animal e compreender o que favorece ou limita o desenvolvimento desses sitemas, a formas mais ecologicamente intensivas. Os sitemas caprinos do Livradois-Forez-França, em um contexto geral, são combinados com outros herbívoros, e são, em parte ecologicamente intensivos se analisados em referência aos princípios agroecológicos. As situações em que esses princípios são seguidos são aquelas caracterizadas por pequenas explorações de pastagem envolvidas no processamento de queijo, visando a autossuficiência na forragem, baixa entrada de insumos, e adaptação à natureza sazonal da produção rebanho caprino. Essas fazendas demonstram que o domínio dos equilíbrios necessários para esse tipo de sistema funcionar de forma agro-ecológica, são construídos progressivamente ao longo do tempo, confirmando a importância do fator tempo. Para obtenção de resultados mais consistentes, e assim, aplicação da intensificação ecológica em outros tipos de sistemas pecuários é preciso continuar este trabalho, refinando-se e incluindo outras práticas de manejo. Além disso, deve-se explorar mais a diversidade dos sistemas produtivos, em diferentes regiões, especialmente no Brasil, onde essa diversidade é mais acentuada do que na França.

Na PARTE II, da Tese, foi apresentado os resultados da inclusão de níveis de sais de cálcio de ácidos graxos do óleo de soja (SCAG) no concentrado de cabras em pastagem. Os resultados sugerem que a adição de até 3,5% do SCAG (35 $g.dia^{-1}$) aumenta o valor energético das dietas. Os sais de cálcio de ácidos graxos também, não altera a produção, composição e qualidade do leite de cabra, bem como não altera o lucro líquido proveniente do leite. No entanto, contribui para o aumento das

concentrações de ácidos graxos poli-insaturados (PUFAs) e de ácido linoleico conjugado (CLA) no leite, podendo assim, ser uma estratégia adequada para melhorar as propriedades funcionais do leite de cabra. Além do que, a adição de SCAG, não limita a ingestão de matéria seca e dos nutrientes e influencia positivamente a fermentação ruminal, aumentando pH e diminuindo o excesso de amônia ruminal. Com isso os SCAG podem ser usados na formulação de dietas para cabras em lactação.