Gabriela Schenato Bica

Hierarquia social e comportamento alimentar de bovinos

Social hierarchy and feeding behaviour of cattle

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Gabriela Schenato Bica

HIERARQUIA SOCIAL E COMPORTAMENTO ALIMENTAR DE BOVINOS

Social hierarchy and feeding behaviour of cattle

Esta Tese foi julgada adequada para obtenção do Título de "Doutora em Agroecossistemas" e aprovada em sua forma final pelo Programa de Pós Graduação em Agroecossistemas - Centro de Ciências Agrárias/UFSC.

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Resumo

A herarquia social de um rebanho bovino pode ser determinante no acesso dos animais aos recursos alimentares, ou seja, animais dominantes (instigadores) apresentam prioridade de acesso aos recursos comparados com animais subordinados (vítimas). Para entender melhor esta relação, nesta tese foram realizados 3 estudos: *Estudo 1,* uma revisão sistemática de literatura (*Social hierarchy and feeding behaviour of cattle: A systematic review*), que buscou publicações de pesquisa relacionadas à dominância social de ruminantes em relação ao seu comportamento alimentar; *Estudo 2,* uma pesquisa original (*Social hierarchy and feed supplementation of heifers: line or piles?*) que avaliou se a distribuição de suplementação (concentrado) em porções individuais garantiria melhor acesso a todos os animais de um grupo, especialmente subordinados, comparada com a oferta de suplemento em linha contínua; *Estudo 3*, também uma pesquisa original (*Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system*), que foi delineado para testar a oferta de suplemento no início e na metade da ocupação do piquete em sistema de Pastoreio Racional Voisin e sua relação com o comportamento alimentar de bovinos. A hierarquia social afeta o comportamento alimentar de bovinos, com consequências diretamente relacionadas às práticas de manejo dos rebanhos adotadas pelos criadores. A suplementação alimentar em pilhas individuais não beneficiou as novilhas subordinadas, uma vez que elas passaram menos tempo ingerindo ração do que as dominantes, independente do tratamento. Ao entrar em um novo piquete, as novilhas dominantes dirigiam-se imediatamente ao suplemento enquanto que as subordinadas pareciam evitar a competição pela ração e dirigiam-se primeiramente ao pasto. Em sistema de Pastoreio Racional Voisin é melhor ofertar a suplementação alimentar no início da ocupação do piquete. Assim, os animais subordinados podem estrategicamente selecionar a pastagem de melhor qualidade enquanto os dominantes se dedicam à ingestão de ração. A oportunidade de selecionar sítios de pastejo com melhor qualidade pode resultar em melhor equilíbrio nutricional ao rebanho.

Palavras-chave: Dominância. Pastoreio rotativo. Comportamento alimentar.

Resumo expandido / Extended abstract

1. Introdução

A dominância social é um componente importante do comportamento social dos animais, e se expressa de acordo com a vontade e a habilidade de cada animal em competir por recursos disponíveis necessários à sua mantença, ao acasalamento, ao descanso, à proteção, à liberdade de movimentos e às interações positivas (PHILIPPS & RIND, 2002). Dentro da hierarquia social podem ser estabelecidas três classes de animais: dominantes, intermediários e subordinados, sendo os primeiros aqueles que obtêm maior número de vitórias ou são mais instigadores, e os últimos perdedores ou vítimas (CRAIG, 1981). A hierarquia social pode influenciar o acesso aos recursos, o que significa, por exemplo, que quanto mais dominante uma vaca é, maior a sua prioridade no posicionamento e a sua influência nos movimentos do rebanho e também de acesso em relação à alimentação, descanso e deslocamentos (SAROVÁ *et al*., 2010). Como resultado, as vacas dominantes acabam consumindo mais suplementos (BOWMAN & SOWELL, 1997), apresentam maior frequência e tempo de ingestão de água (COIMBRA *et al*., 2012; HÖTZEL *et al*, 2013) e consomem a forragem de melhor qualidade (BARROSO *et al*., 2000) em comparação às vacas subordinadas. Assim, a temática abordada nesta tese de doutorado é a compreensão das relações entre a hierarquia social de bovinos e o comportamento alimentar, especialmente referente à ingestão de pasto e suplementação.

Para tanto, a tese engloba três estudos inter-relacionados: o *Estudo 1* é uma revisão sistemática de literatura (*Social hierarchy and feeding behaviour of cattle: A systematic review*), cujo objetivo foi revisar publicações de pesquisa relacionadas à dominância social de ruminantes em relação ao seu comportamento alimentar. O *Estudo 2* é uma pesquisa original (*Social hierarchy and feed supplementation of heifers: line or piles?*) que avaliou se a distribuição de suplementação (concentrado) em porções individuais iria garantir melhor acesso aos bovinos, especialmente subordinados, comparada com a oferta de suplemento em linha contínua; ao observar o comportamento das novilhas durante o estudo 2 no qual o suplemento era ofertado para todos os animais no momento da entrada da ocupação do piquete, decidimos realizar um novo experimento para ver se o comportamento se mantinha quando a oferta de suplemento ocorresse durante a

ocupação do piquete, o que resultou no *Estudo 3*, que também é uma pesquisa original (*Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system*), e que foi delineado para testar a oferta de suplemento no início e na metade da ocupação do piquete em sistema de Pastoreio Racional Voisin e sua relação com o comportamento alimentar de bovinos.

2. Estudo 1 - Social hierarchy and feeding behaviour of cattle: Systematic review

2.1 Metodologia

A revisão sistemática foi realizada na base de dados Web of Science, considerando artigos originais de pesquisa publicados entre janeiro de 1975 e julho de 2018. Foram utilizados termos de busca específicos (" *(TS=((cattle OR "dairy cattle" OR bovine OR heifer OR cow OR "farm animal" OR livestock OR ruminant OR calf OR calves OR ungulat* OR sheep OR deer OR goat OR Capra hircus) AND ("social behav*" OR "social hierar*" OR "social rank" OR "low-rank" OR "social stress" OR "social dominan*" OR "positive interaction" OR "negative interaction" OR "agonistic interaction") AND (grazing OR supplement OR "water intake" OR "water ingestion" OR "pasture intake" OR feed OR food OR silage OR grain OR "feed bunk" OR "water trough" OR feeder OR "feeding space"))) AND IDIOMA: (English) AND TIPOS DE DOCUMENTO: (Article).*") e os resultados foram filtrados gradativamente de acordo com título, abstract e texto na íntegra. Foram excluídos 1) livros, revisões, comunicados e qualquer arquivo que não fosse artigo de pesquisa original; 2) não relacionados a ruminantes; 3) artigos relacionados a comportamentos reprodutivos, síndromes, ou qualquer comportamento que não relativo ao comportamento alimentar; 4) artigos sobre tempo em pé/deitado sem relação com o comportamento alimentar; 5) artigos sobre manejo, transporte, qualidade de produto que não relativo à alimentação; 6) artigos publicados em qualquer lingua que não o inglês.

2.2 Resultados

Foram selecionados previamente 418 artigos, os quais foram filtrados e selecionados 26 que atendiam a todos os critérios de pesquisa para análise. A maioria dos estudos (77%) foram realizados com bovinos de leite e 70% dos artigos foram publicados entre 2000 e 2018; 92% foram realizados com animais suplementados sendo que as interações agonísticas eram observadas durante a alimentação, e apenas

8% foram realizados com animais à pasto; Foram identificados mais de 10 métodos diferentes para a determinação da hierarquia social.

2.3 Conclusões

Com base nos estudos analisados fica evidente que a hierarquia social afeta o comportamento alimentar de bovinos, com consequências diretamente relacionadas às práticas de manejo dos rebanhos adotadas pelos criadores.

3. Estudo 2 - Social hierarchy and feed supplementation of heifers: line or piles?

3.1 Metodologia

Para testar dois tratamentos: LINE (1m linear de ração/animal) e PILE (uma porção/novilha distante 1m umas das outras) foram utilizados quatro grupos de nove novilhas cada, num desenho experimental tipo *cross-over*. Cada período contou com três dias de habituação seguidos por sete dias de coleta de dados. Os animais eram criados em sistema de Pastoreio Racional Voisin e as observações ocorreram por uma hora a partir da entrada dos animais no piquete (8 às 9h) em instantâneos de cada animal a cada um minuto. O comportamento foi registrado como pastando, ingerindo suplemento, disputando e outros. Todas as interações agonísticas foram registradas e utilizadas para o cálculo da matriz sociométrica para cada grupo. Cada novilha foi, então, definida como dominante, intermediária e subordinada.

3.2 Resultados

Embora o tratamento não tenha afetado o comportamento ingestivo dos animais, houve uma tendência de maior disputas pelo suplemento quando este era ofertado em pilhas do que em linha (P = 0,09). Houve efeito da hierarquia social no comportamento alimentar. Vacas dominantes e intermediárias dedicaram mais tempo ao consumo de suplemento do que as subordinadas ($P \leq 0,03$), as quais passaram mais tempo pastando do que as demais ($P \leq 0,01$). A hierarquia social foi correlacionada com o peso inicial dos animais (r= 0,70; $P \leq 0,0001$).

3.3 Conclusões

Oferecer a suplementação alimentar em pilhas individuais não beneficiou as novilhas subordinadas, uma vez que elas passaram menos

tempo ingerindo ração do que as dominantes independente do tratamento. Diariamente, ao entrar em um novo piquete, as novilhas dominantes dirigiam-se diretamente ao suplemento enquanto que as subordinadas pareciam evitar a competição pela ração e dirigiam-se ao pasto. Consequentemente, enquanto dominantes ingeriam ração as subordinadas ingeriam pasto, em uma possível estratégia para evitar confrontos e conseguir escolher melhores sítios de pastejo.

4. Estudo 3 - Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system

4.1 Metodologia

Em um sistema de Pastoreio Racional Voisin, dois grupos (1=15 novilhas; 2=19 novilhas) foram testados num delineamento *cross-over* em dois tratamentos: AM (suplementação oferecida pela manhã/8 h, no início da ocupação do piquete) e PM (suplementação oferecida pela tarde/16 h, na metade do tempo de ocupação do piquete). A ração era oferecida em linha contínua (1m/animal) abaixo da linha da cerca na base de 2kg/animal/dia. O período experimental contou com sete dias de habituação seguidos por dois períodos de 35 dias cada para a coleta de dados. Os comportamentos foram observados durante duas horas a partir do oferecimento da ração, de acordo com o tratamento (8-10h; 16-18h). Foram feitos instantâneos a cada dois minutos para registrar os comportamentos de pastando no piquete, pastando perto da cerca, ingerindo suplemento e outros. Todas as interações agonísticas foram registradas e utilizadas para o cálculo da matriz sociométrica para cada grupo. Cada novilha foi, então, classificadas como dominante, intermediária e subordinada. Semanalmente foi realizada coleta de pasto pela metodologia *hand plucking* para análise de proteína bruta (PB) e fibra em detergente ácido (FDA) e fibra em detergente neutro (FDN).

4.2 Resultados

As novilhas foram observadas mais tempo pastando no tratamento AM ($p<0.0001$) e realizando outros comportamentos no tratamento PM ($p<0.0001$). As novilhas dominantes foram observadas mais tempo ingerindo suplemento do que as subordinadas ($p=0.0008$) que por sua vez passaram mais tempo pastando ao longo do piquete ($p=0.0067$). O teor de PB das amostras da pastagem consumida coletadas foi maior no

tratamento AM ($p<0.0001$). Houve interação entre a hierarquia social, o teor de PB da amostra da simulação de pastejo e a ordem em que os animais deixavam a área de fornecimento da ração e iniciavam o pastoreio ($P = 0.04$).

4.3 Conclusões

Em sistema de Pastoreio Racional Voisin é melhor ofertar a suplementação alimentar no início da ocupação do piquete. Dessa forma os animais subordinados podem selecionar a pastagem de melhor qualidade enquanto os dominantes se dedicam à ingestão de ração. A oportunidade aos subordinados de escolher os melhores sítios de pastejo pode resultar em melhor equilíbrio nutricional ao rebanho.

5. Considerações finais

Os animais dominantes tem prioridade de acesso aos recursos do ambiente (MIRANDA-DE-LA-LAMA *et al*., 2011). Em ruminantes, a dominância está relacionada à prioridade de acesso às melhores áreas de pastejo (BARROSO *et al*., 2000) e sendo assim, a hierarquia social precisa ser levada em consideração quando se planeja ou maneja um rebanho. Em alguns casos os animais subordinados adotam diferentes estratégias para lidar com situações desafiadoras e com isso alteram seus comportamentos e a ingestão de alimentos. Apesar disso, os programas de suplementação alimentar devem ser planejados para mitigar os efeitos negativos da dominância social, que podem ser impactantes mesmo para animais em pastejo. Em sistemas de criação à pasto, as sinergias entre as decisões tomadas pelos animais e pelos criadores têm o potencial de oferecer benefícios para os rebanhos, para o ambiente e os seres humanos (GREGORINI, 2017). De acordo com os resultados aqui apresentados, e que confirmaram nossa hipótese, os animais criados à pasto em sistema rotativo, com mudanças frequentes de piquete (assim como o Sistema de Pastoreio Racional Voisin/PRV) devem receber a suplementação alimentar no momento em que entram em um novo piquete, independente da forma de oferta ser em linha ou em porções individuais. Percebemos que dessa forma os animais subordinados tem a oportunidade de selecionar os melhores sítios de pastejo enquanto os animais dominantes consomem o suplemento (grãos ou ração).

Abstract

The social hierarchy of a cattle herd can be determinant in the access of animals to feed resources, that is, dominant animals (instigator) have priority access to feed compared to subordinate animals (victims). To better understand this relation, this thesis we present 3 studies: Study 1, a systematic literature review (*Social hierarchy and feeding behaviour of cattle: A systematic review*) about published research articles related to social dominance regarding to feeding behaviour; Study 2, an original research study (*Social hierarchy and feed supplementation of heifers: line or piles?*) that evaluated if distributing feed supplement (concentrate) in individual piles would grant better access to all animals in a given group, specially subordinate ones, compared to the feed offer in a continuous line; Study 3, another original research study (*Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system*) designed to test the effects of supplement offer at the beginning or at half-time of paddock occupation on Voisin's rational grazing system on cattle feeding behaviour. The conclusion is that social hierarchy affects cattle feeding behaviour with consequences directly related to the management practices adopted by the farmers. Feed supplementation in individual piles did not benefit subordinate animals as they spent less time ingesting supplement than the dominant ones, regardless of treatment. When entering a new paddock with supplement offer, the subordinate heifers seemed to avoid competing for grain and spent more time grazing while the dominant ones spent more time eating supplement. In Voisin's rational grazing system it is better to offer grain supplement when the animals get into a new paddock. Subordinate heifers can choose to graze best quality patches while the dominant heifers eat grain supplement instead of graze along the paddock and prevent the other animals of selecting the best feeding sites. The opportunity to select the best grazing patches may result in a better nutritional balance among the herd.

Keywords: Dominance. Rotative grazing. Feeding behaviour.

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1. General introduction

Animal husbandry needs to be efficient and competitive while promoting animal welfare and food security (DAWKINS, 2017). However, intensification of breeding systems, with more numerous herds and not accompanied by adequate infrastructure, results in behavioural indicators such as competition for feeding resources and rest areas (PROUDFOOT & HABING, 2015). Livestock engage in behaviours that are shaped by consequences (intentionally or unintentionally) to produce desirable or undesirable outcomes. A farmer who understands livestock behaviour can also enhance the likelihood of success when making a change in grazing systems (BRUNSON & BURRITT, 2009). For an efficient and respectful animal husbandry, it is necessary to understand if the animals are healthy and if they have access to what they need (DAWKINS, 2004). An adequate management and supply of food and water may minimize conflicts and provide positive social interactions (BROOM & FRASER, 2015).

For Boyland (2016), social relationships have a significant impact on individual and group success, but there are still gaps in our knowledge of how farmed animals respond to their social environment, which varies greatly between farms and is unstable due to the constant regrouping of animals. Outside the scientific world the effect of social behaviour on production is little taken into account, but the importance of this relationship has been sufficiently proven in most species (BARROSO *et al*., 2000). The social hierarchy of cattle play an important role on the animals access to environmental resources such as food and water, either if they are raised confined or on pasture. As we do understand that importance, this thesis addresses this issue and it brings the discussion of strategies used by subordinate animals and farmers to mitigated this behaviours, specially for grazing animals.

This thesis is divided in three parts: the first one is a systematic review (*Social hierarchy and feeding behaviour of cattle: Systematic review*) that aimed to search and review studies relating social dominance of farmed ruminants to the access to feeding behaviour, feed resources and supplementation. The second part is an original research (*Social hierarchy and feed supplementation of heifers: line or piles?*) designed to evaluate if distributing grain supplement along the fence in

individual piles would grant better access to the animals, specially subordinate ones, compared to supplement in continuous line. The third part is another original research (*Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system*) designed to test different delivery times (at the beginning x half time of paddocks' occupation) of grain supplement on feeding behaviour of heifers.

2. General objective

The objective of this thesis was to investigate the effects of social dominance on feeding behaviour of cattle and their access to feed supplementation on rotational grazing systems.

2.1 Specific objectives

- To perform a systematic review to investigate studies concerning to cattle social dominance and its effects on their access to feed resources;
- To evaluate if distributing grain supplement along the fence in individual piles would grant better access to subordinate animals, compared to supplement in continuous line;
- To evaluate if delivering grain supplement at the beginning of paddock use (in a rotational grazing systems where the animals get into a new paddock everyday) would affect heifers behaviour compared to supplement delivery at half-time of paddock usage;

3. Literature review

3.1 Social behaviour

Bovine are social animals and use complex channels of communication between individuals. Social interactions form the means of communication for information to be transferred (PHILLIPS, 1993). Social behaviour is defined as the tendency to form interdependent and cooperative relationships, and to live and reproduce in more or less organized communities (WEBSTER, 1980). It includes relative behavioural patterns involving two or more members of the same species with respect to organization, aggression, territoriality, reproduction, parental and cooperative care (BANKS & HEISEY, 1977). These behaviours are influenced by the presence or absence of another individual, so the interactions can be divided into non-agonistic (sexual and affiliative behaviour) and agonistic (aggression and escape / avoidance) (KEELING & GONYOU, 2001).

Affiliative interactions are behaviours such as allogrooming (GUTMANN *et al*., 2015), play behaviour (VALNÍCKOVÁ *et al*., 2015) and preferential spatial associations between individuals (VAL-LAILLET *et al*., 2009). Competitive interactions are evidenced mainly by the dispute of resources such as food (LLONCH *et al*., 2018), water (COIMBRA *et al*., 2012) and shade (VIZZOTTO *et al*., 2015).

3.2 Affiliative interactions

"Affiliative behavior is characterized by maintaining proximity, providing food, protection or allogrooming between specific individuals" (BOISSY *et al*., 2007). In general, positive effects of affiliative behaviour can be attributed to improved group cohesion, building or strengthening of bonds between group mates and reduced aggression (LINDBERG, 2001).

Among the frequent affiliative behaviours of the social repertoire of a herd is grooming, which implies in a coordinated, sporadic, short-lived and repetitive tactile contact between individuals of a species. This contact occurs through the tongue, lips, teeth or an appendix (paws, horns) (BRAN *et al*, 2013). Licking can be reciprocal or not and occurs more frequently among animals that are directly related (SATO 1993;

TAKEDA, 2000; GYGAX, 2010). It is likely to have a role in conflict resolution, social tension reduction (SATO, 1984; VAL-LAILLET *et al*., 2009; LAISTER *et al*., 2011) and maintenance of social cohesion (DUNBAR, 2010).

The relationship between grooming and social hierarchy is not yet well determined. Some authors hypothesize that grooming is performed by subordinate individuals in dominant ones (FRASER & BROOM, 1990; PHILLIPS & RIND, 2002), while other studies do not confirm this relationship (SATO *et al*., 1991; TRESOLDI *et al*., 2015). Sarová *et al*. (2016) have found that the allogrooming behaviour was mostly oriented down the hierarchy and that the very active high ranking allogroomers exchanged a lot of the licking with each other. The amount of grooming observed between two individuals can be used as an index of the degree of affiliation or friendship between them (WASILEWSKI, 2003; BOISSY *et al*., 2007, TRESOLDI *et al*., 2015).

There is evidence that social factors, including deprivation of social contact (isolation), reduction of space (agglomeration) and social disturbances (social instability) trigger physical and behavioral stress indicators in beef cattle (PROUDFOOT & HABING, 2015). The social position may influence how animals are ordered relative to others in the group (SAROVÁ *et al*., 2010), how close to the center of the herd they are (KABUGA, 1993; HEMELRIJK, 2000) and how they play with the others (FLACK *et al*., 2006). Therefore, the importance of friendship relationships within social groups has been recognized (LINDBERG, 2001) and detailed as a voluntary, reciprocal and non-reproductive intentional relationship between animals (WASILEWSKI, 2003). In dairy cows, friendship is demonstrated by a more frequent occurrence of affiliative behaviors among friends (VAL-LAILLET *et al*., 2009).

The presence of an animal considered as a friend has a calming effect when there is exposure to new physical and social environments (BOISSY *et al*., 1997; VEISSIER *et al*., 1992). In addition, cows that have affective bonds become less ill and are better adapted to stressful situations than are the solitary cows (WAIBLINGER *et al*., 2006). In the study performed by Mulleder (2003), beef cows presented different behavioural strategies, consistent between situations of high and low social competition: cows of intermediate social position avoided agonistic interactions and calmed dominant ones through positive interactions, initiating affiliative behaviours more often than the others. Living in social group has advantages and disadvantages. For example,

it facilitates reproduction and predator protection, but for the individual it can also be negative in terms of increasing forced social contact with dominant animals and competition for different resources.

3.3 Competitive interactions

Competitive interactions naturally occur in a group of animals, but are worsened by the conditions of the rearing environment, especially in more conventional intensive systems. Social dominance can be considered as a behavioural variable with a determinant role in the welfare of farm animals, since it affects the access to all resources of the environment (KEELING & GONYOU, 2001).

The dominance relationship in a pair of animals is a result of a learning process that involves different factors in their initial formation (Beilharz & Zeeb, 1982). According to Drews (1993), dominance may be related to an individual physical characteristic or to an attribute resulting from the encounter of a pair; it can be associated with aggression or lack thereof; and be based on theories or observable behaviours. It is the result of a pattern of repeated agonistic encounters between two individuals whose outcome is always (or almost always) favourable to one individual and negative to the other. Thus, it can be described in 3 levels of analysis: individual level (frequency in which an animal initiates or receives an agonistic interaction), dyad level (asymmetric dominance between 2 individuals) and group level (transitive dominance that results in a linear order of classification) (LANGBEIN & PUPPE, 2004). In cattle, social hierarchy is not linear, but with a tendency to be linear, with triangles or ties.

Thus, social hierarchy represents the phenomenon in which the behaviour of an animal can be inhibited by the behaviour of another and is related to age, size and body weight, as well as the presence of physical attributes such as horns (BOUISSOU, 1972). Although size and weight are correlated with age, the social skills needed to gain a high position in the hierarchy need to be learned and, in addition, emotion or fear are also components in hierarchical determination, varying in degree of importance between individuals (PHILLIPS , 1993).

For Bouissou *et al*. (2001), it is almost impossible to control other factors since age is associated with body weight, experience and seniority in the group. For Harris (2007) and Sarová *et al*. (2013), the age, rather than body mass, has a positive correlation with dominance

in beef cows. When evaluating a group of animals for 10 years Sarová *et al*. (2013) concluded that relationships are initially established by asymmetry between younger and older animals and develop in a highly transitive structure. In the study by Butterworth & Van Dijk (2016) heifers occupied the lowest positions in the hierarchy when compared to cows in the third lactation.

The direction of dominance in a pair of animals is initially determined by one or more aggressive interactions and learning is part of maintaining the relationship. The aggressive interactions between two or more animals, related to struggle or dispute involving (or not) physical contact are called agonistic interactions (Beilharz & Zeeb, 1982); submission is the surrender response of an animal to an aggressive action initiated by another animal; and subordination is the condition of the loser animal in successive disputes and conflicts (DREWS, 1993).

Social familiarization involves processes of conditioning (with positive or negative reinforcement) and the time required to establish the hierarchy in a group of cattle depends on the size of the group but, in general, most relationships are established within one hour after grouping (BOUISSOU *et al.*, 1974 and 1980). The tendency is that the agonistic interactions with physical contact are limited mainly to the first few hours and days after grouping, and then there are more threats and avoidance than physical contact (KONDO & HURNIK, 1990).

It is possible to say that dominance is the instrument of the hierarchy, mediated by agonistic interactions. The hierarchical order of a group can be determined by an index based on the number of agonistic interactions that an animal won and lost regardless of the identity of the other individual involved in the dispute (GALINDO & BROOM, 2000); by an index based on the number of individuals dominated or subordinated regardless of the frequency of social interactions (DeVRIES *et al*., 2004) or by a mixture of both methods, as proposed by Kondo & Hurnik (1990).

The sum of relations of dominance (aggression-avoidance or instigation-subordination) results in the social hierarchy of the group, with rank representing the relative position of an animal compared to others in the group. The winning animal has the status of dominant, while the loser is the subordinate. Thus, dominance status refers to

dyads, whereas dominance rank (high or low) refers to the position in the hierarchy and thus depends on the composition of the group (DREWS, 1993). The asymmetry of disputes is the result of consecutive victories of one individual over another and once learned, the dominance relationship for each pair persists for a long time.

The time required to establish the hierarchy in a group may determine its stabilization rate (KONDO *et al*., 1984). In younger animals the relations are bidirectional while in more mature animals there is clearly more unidirectional relations of dominance (DREWS, 1993). The social rank is different for each group of animals, it depends not only on the individual atributes (age, weight, etc) but also on individual motivation for a given resource (VAL-LAILLET *et al*., 2008) and it can be altered by adding or removing individuals (HASEGAWA *et al*., 1997).

The increase in agonistic interactions due to the high concentration of animals in an area with forced physical contact with animals of higher hierarchical positions and frequent exposure to unknown herds causes social stress resulting in increased adrenal gland weight of subordinate animals (BOUISSOU, 1980; GONZALEZ *et al*., 2003). In some species, subordination has been related to chronic stress responses, which can be measured by glucocorticoid / catecholamine hyper-secretion, elevated blood pressure, a higher incidence of stress-related diseases (SOLANO *et al*., 2004) and of laminitis (GALINDO & BROOM, 2000). Huzzey *et al*. (2012) found that cows of low social status, regardless of age, had the highest rates of cortisol in feces, in response to the crowding in the feed trough.

3.4 Social behaviour and access to resources

Access to resources is influenced by social behaviour and the priority of access by the dominant animals or positioned at the top of the hierarchical order of a group has been reported by several authors. This pattern reflects the classic image of social dominance in which resources are accessed disproportionately, inequalities are maintained through aggression / intimidation, and consequently subordinate animals are subject to severe resource constraints and physical and social stressors not only in farmed ruminants but in wild baboon too as stated by Sapolsky (1992).

High ranking cows have priority access to facilities (SOLANO *et al*., 2004), eat more and are heavier (MANSON & APPLEBY, 1990; BOUISSOU *et al*., 2001) and have greater weight gain (PHILLIPS & RIND, 2002) when compared to intermediate and low rank animals. In rotative grazing system, dominant cows drink more water and more often than the subordinates if the water trough is allocated in the corridor (COIMBRA *et al*., 2012). The dominant cows also have priority of access to the milking parlour (SOFFIÉ, 1976), produce more milk (VAL-LAILLET *et al*. 2008), spend more time on the water trough after feed delivery (VAL-LAILLET *et al*., 2008) and have higher dry matter intake than the subordinate cows (MANSON & APPLEBY, 1990). This pattern also happens when the cows have access to robotic milking, as the dominants visit it more often and wait less time to be milked than subordinate ones (JAGO *et al*., 2003). Dominant steers also present longer feeding times and higher feeding frequency than the others in the group (LLONCH, 2017).

If dominant animals have priority access to food and water, especially when resources are limited, the subordinate animals may suffer severely from such restriction and eat and drink less than necessary with negative repercussions on their productivity, reproduction, health and general well-being (MACHADO FILHO *et al*., 2015). In highly competitive situations the dominant cows spend more time in the feed trough and thus the subordinate cows are forced to change their eating behaviour and eat food at alternative times, when they would not normally feed (OLOFSSON, 1999).

Dominance may also be affected by the animal's motivation or persistence in having access to a particular food or resource. The motivation to perform a behavior depends on the interactions between internal and external factors, which involve feedback control mechanisms (GALINDO *et al*., 2000) and can be determinant of competitive success in dairy cows (VAL-LAILLET *et al*., 2008).

If an important resource such as water, food, or resting area becomes restricted, the motivation of an animal to engage in a struggle will be stronger than if the same resources are freely available (KONDO & HURNIK, 1990). Subordinate dry cows with restricted access to water visit the water trough in alternate days while lactating cows competed for water every day, regardless of its hierarchical position (HÖTZEL *et al*., 2003). When heifers were consuming the TMR (total mixed ration) portion of the ration, they were highly

motivated to consume the feed rather than engaging in competitive behaviour but it is likely that at lower levels of feed bunk space, this competition would increase (KITTS *et al*., 2011).

Despite all the advantages related to dominant animals, it is possible that subordinate animals use different strategies to overcome social and environmental adversities. Individual differences in animal behaviour and physiology have been explained through personality traits, styles, or strategies (ERHARD & SCHOUTEN, 2001). The idea of strategy can be defined as a behaviour, or a set of behavioural patterns, used by an individual to achieve a certain goal (MENDL & DEAG, 1995).

There are evidences that the strategy used by an animal in response to its social environment is more important to its physical and mental health than its social position. Individual differences in the way a situation is perceived may be related to the concept of coping strategy, that is the different behavioural and physiological strategies used by an animal to deal with challenging situations. In certain circumstances, individuals who appear to be less successful in social competition are successful in terms of performance (MENDL & DEAG, 1995), i.e., subordinate animals are not necessarily worse than dominant ones. Low rank animals adopt a passive strategy, as a result of giving up trying to reverse their situation on a stressful event (SOLANO *et al*., 2004).

3.5 Social hierarchy and feed supplementation

Supplementation with concentrates, hay or silage is a common practice for cattle. In Southern Brazil, the practice of feed supplementation for cattle can be recommended to minimize the effects of seasonal fluctuations of pastures (PINHEIRO MACHADO, 2010; COSTA *et al*., 2013) or as an important daily supplement for high productivity cows (PINHEIRO MACHADO FILHO *et al*., 2015). According to Wendling & Machado Filho (2018) the farmers are heavily dependent on maize silage as a mean to ensure annual availability of feed and to increase milk production, although they lack the use of technical criteria for the production and supply of silage to dairy cows. The correct use of feeding programmes may overcome nutritional deficiencies in pastures and bring positive effects to the rearing system (MACHADO FILHO *et al*., 2014).

Food supplementation programs that aim to maximize animal weight gain or increase milk production of the herd mainly consider aspects such as animal category, nutritional requirements, pasture stage, and also supplement or labour costs. But the effectiveness of these programs is affected by the ability to reduce variation in intake and effectively meet their intended goals. Intake of supplement is generally evaluated by dividing the amount of supplement provided by the number of animals in the group, excluding leftover from the trough. However, it does not consider individual variation in intake influenced by social behaviour.

The amount of animals that do not consume supplement is increased by the limitation of trough space, little quantity of supplement, form and formulation of the supplement, aspects inherent to grazing, neophobia to food or trough and other aspects related to group feeding, such as social interactions (BOWMAN & SOWELL, 1997 and 2002). A high coefficient of variation in supplement intake in a group of cows (CV of 95-150%) was found by Bowman e Sowell (2002); the 2-year-old animals consumed only traces of the supplement offered compared to the 3-year-old animals.

For Rioja-Lang *et al*. (2012), as long as all animals consume sufficient food within 24 hours, the feeding area does not need to accommodate all animals at the same time. However, in confinements where food supply is not *ad libitum*, animals that do not adapt well to competitive environments may be at a disadvantage in terms of the quantity and quality of food they access (ZOBEL, 2011). By providing adequate space in the feeder and allowing all animals to feed at the same time it is possible to improve feed efficiency and average daily gain (GRETER *et al*., 2013) as well as to increase the motivation of the subordinate animals to access the feed (RIOJA -LANG *et al*., 2012). Cattle have circadian rhythms, having two major meals per day (early morning and late afternoon) and eat in social. Animals left to eat out of this time, will eat less than the others.

The greater the space in the trough, the greater is the feeding activity and there is less competition among cows. Aggressive interactions decreased 57% when trough spacing was 1m / animal, compared to 0.5m / animal and thus the subordinate cows spent more time feeding during the day (DeVRIES *et al*., 2004). The same logic was pointed out by Greter *et al*. (2011), whose work showed that the provision of more spacing in the trough (0.68x0.34m / heifer) is

beneficial for the behaviour of the animals. On the other hand, in a study by Greter *et al*. (2013) more space in the feed trough did not affect the competition, however, the average daily weight gain was higher when the spacing was 0.40m / heifer compared to 0.29m / heifer.

Despite the widespread use of feed troughs in feedlot or housing systems, for cattle raised on grazing systems the fence-line feeding or strip feeding is an alternative to the use of troughs as it can allow all animals to feed at the same time, according to the conditions of the rearing system, thus reducing competition for food or space (GRANT & ALBRIGHT, 1995).

All this knowledge about the social hierarchy of cattle shows and justifies the need of more research on this subject, especially with regard to mitigating the negative effects of the dominance-subordination relations, with focus on cattle raised under grazing systems because many publications currently available are related to studies with confined animals.

4. Study 1

Social hierarchy and feeding behaviour of cattle: a systematic review

Abstract

Feeding is of major importance for animal husbandry systems and it is influenced by social dominance and farm management. The objective of this review was to search for published research articles about the social dominance of farmed ruminants regarding to feed resources. A systematic review was performed between December 2017 and July 2018 on the "Web of Science" on-line scientific database. In a multi-step process we selected 26 articles out of 418 that matched all our pre-defined search strings. Most articles (70%) were published between 2000 and 2018 and were performed using dairy cattle on confinement systems. There were more than 10 different methods to determine the social hierarchy or the social rank. All selected studies have shown the consequences of social hierarchy for the animals such as decrease in dry matter intake and lower weight gain; high level of agonistic encounters (fights) and cortisol, as well as changes in normal animal behaviour. The different strategies used by cattle pointed out by the authors also lead to an understanding that the low rank animals are not necessarily worst in terms of coping and performance compared to high ranking animals. What is clear in all studies' conclusions is that the social dominance does affect feeding behaviour of cattle, with more or less consequences according to the management practices.

Keywords: Dominance. Animal husbandry. Animal behaviour.

4.1 Introduction

Feeding patterns of farmed ruminants are influenced by several factors including the social behaviour which affects or is affected by the presence or the action of another individual and it is determinant for the welfare of farm animals (KEELING & GONYOU, 2001). The social dominance is an important component of social behaviour of cattle and is expressed according to the willingness and the ability of each animal to fight for scarce resources (PHILLIPS & RIND, 2002), required for maintenance, mating, rest, protection, freedom of movement and positive interactions.

The social hierarchy of a given group is a result of constant agonistic interactions (instigation, aggression, avoidance) of one individual over another, performed either to acquire a resource or to defend it against conspecifics. The intensification of animal rearing systems without adequate infrastructure or management have led to higher levels of competition for food or resting areas (PROUDFOOT & HABING, 2015). When resources are plentiful, animals in a herd commonly feed and rest together, and dominant animals displace subordinates less frequently. However, the absence of agonistic encounters does not refute the existence of dominance hierarchies (SOWELL *et al.*, 1999).

In ruminants, dominant animals are known to have priority access to resources (cattle: VAL-LAILLET *et al*., 2008; SAROVÁ & SPINKA, 2010; COIMBRA *et al*., 2012; red deer: APPLEBY, 1980; CEACERO *et al*., 2012; sheep: ERHARD *et al*., 2004). As a consequence the subordinate animals may suffer negative impacts on their performance and welfare (MIRANDA DE LA LAMA *et al*., 2013; LLONCH *et al*., 2018). Even in primates, when resources are limited or accessed disproportionately, the social inequalities are maintained through aggression or intimidation and consequently dominant animals have priority access and subordinate animals may suffer a severe restriction of these resources (SAPOLSKY, 1992).

Management factors may contribute to the expression of the negative effects of social dominance over feeding behaviour such as space allowance, access to feeding area, frequency of feed delivery and others besides physiological aspects as motivation.

As feeding is a crucial point of animal husbandry systems and we know it is influenced by social dominance and farm management,

our objective is to review the current knowledge about the social dominance of farmed ruminants regarding to feed resources and to understand how the authors address the mitigation of possible negative effects of hierarchy and alternatives to improve feeding management of farm animals.

4.2 Methodology

In order to identify studies focusing on the relation between social dominance and feeding behaviour of farmed ruminants, a systematic review was performed between December 2017 and July 2018 using the Web of Science scientific on line database (*www.webofknowledge.com*), searching for articles published from 1975 to 2018. The restricted search strings used are described in Table 1.

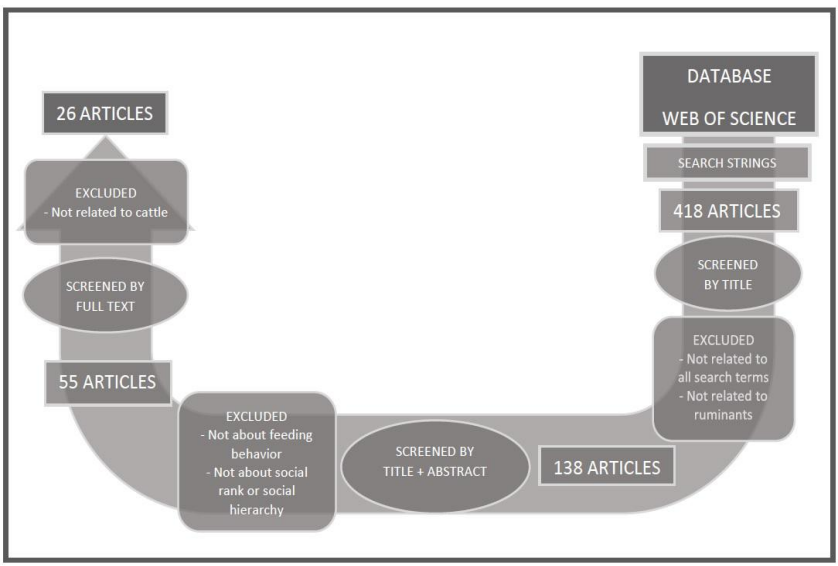
Table 1. Search strings used on the Web of Science database for the systematic review, 2018.

Category	***Search strings***
Animal	*cattle OR "dairy cattle" OR bovine OR heifer OR cow OR "farm animal" OR livestock OR ruminant OR calf OR calves OR ungulat* OR sheep OR deer OR goat OR Capra hircus*
Social behaviour	*"social behav*" OR "social hierar*" OR "social rank" OR "low-rank" OR "social stress" OR "social dominan*" OR "positive interaction" OR "negative interaction" OR "agonistic interaction"*
Feed management	*grazing OR supplement OR "water intake" OR "water ingestion" OR "pasture intake" OR feed OR food OR silage OR grain OR "feed bunk" OR "water trough" OR feeder OR "feeding space"*
Language	*English*
Type of document	*Article*

To identify the relevant studies for the purpose of this review a multi-step process was applied. First, articles were identified via search terms in the database. Than the reference list with the relevant articles was screened by title and then by abstract always according to the

search strings. Finally the remaining articles were screened by full text. Only articles that m*et al*l the criteria defined were selected. The results were filtered according to the following criteria of exclusion: 1) books, reviews, short communications, or any other than research article; 2) not related to farmed ruminants (only cattle, sheep, deer, goat, buffalo); 3) related to reproductive behaviour or behavioural syndromes; 4) related to behaviours as laying or standing but not directly related to feeding behaviour; 5) articles regarding to handling, transport and product quality; 6) articles published in any other language than English. As a final step, based on the full articles, only studies related to cattle were selected for this review. The number of articles selected and the exclusion process are shown in Figure 1.

Figure 1. Flow chart describing the search multi-step process, from defined search strings to final selected articles.



4.3 Results

In the Web of Science database, the first screen based on the search strings resulted in 418 articles selected. From this all titles were reviewed and selected 138 articles. The third selection was based on the full article and resulted in 55 articles related to social hierarchy and relation to feeding behaviour of ruminants (Figure 1).

From the 55 selected articles that published assessments on social hierarchy and its relation to feeding behaviour of ruminants, 47% were with cattle (n=26), 24% with deer (n=13), 15% with goat (n=8), 11% with sheep (n=6) and 4% with buffalo (n=2). As our main objective was to understand that relation in cattle, the results discussed below are based on the 26 articles related exclusively to cattle (cows, calves, steers, heifers).

Overall the selected studies, 35% (n=9) were published between 2000 and 2010, 35% (n=9) between 2010 and 2018, 23% (n=6) articles in 1990/2000, 7% (n=2) in 1980/1990 and none from 1970 to 1980. Regarding to where these studies were carried out, Canada and Sweden hosted 3 studies each, followed by USA, Scotland, Gana and Japan with 2 studies each. India, Austria, Spain, Australia, UK and Brazil were responsible for 1 study each. There were 7 studies that did not mention where it was realized. In 92% (n=24) of the studies the animals received supplement and the agonistic interactions or the displacements were observed during feeding time; only 8% (n=2) studies were realized on pasture. Most of the studies (77%; n=20) were performed with dairy cattle of different ages (cows, heifers, calves) and physiological status (pregnant, lactating, dry). The other 23% (n=6) where with beef cattle (steers, cows, heifers and calves). There were more than 10 different methods to determine the social hierarchy or the social rank as shown in Table 2.

Table 2. Overview of selected articles (n=26) about social hierarchy and feeding behaviour of cattle, based on Web of Science database. From 1975 to 2018.

Title	Authors	Journal	Year	Animals	Determination of social rank or hierarchy
A note on the effect of social rank on the feeding-behavior of young cattle on self-feed maize silage	Leaver, J.D.; Yarrow, N.H.	ANIMAL PRODUCTION	1980	dairy heifers	not detailed (dominance-submission interactions recorded)
Eating behavior, social-dominance and voluntary intake of silage in group-fed milking cattle	Harb *et al.*	GRASS AND FORAGE SCIENCE	1985	dairy cows	Angular dominance values (ADV) (Beilharz and Cox, 1967)
Social-status and its relationships to maintenance behavior in a herd of ndama and west african shorthorn cattle	Kabuga *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	1991	beef cows	Dominance values (DV) (Beilharz and Zeeb, 1982)
Social interactions in ndama cows during periods of idling and supplementary feeding post-grazing	Kabuga	APPLIED ANIMAL BEHAVIOUR SCIENCE	1992	beef cows	The number of dominated cows and the ratio of agonistic interactions (AI) originated by an animal to total number of AI in which an animal was involved were calculated for each cow. Herd was divided into three groups: high, medium and low ranking cows
The influence of social hierarchy on the time budget of cows and their visits to an automatic milking system	KetelaardeLau were *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	1996	dairy cows	Dominance value of Cow A = no. of cows subordinate to cow A / no of known dominance relationships of Cow A (Sambraus, 1975). Cows with dominance value > 0.60 were classified as high ranking, cows with 0.60 > dominance value > 0.40 as middle ranking and cows with dominance value < 0.40 as low ranking
The effects of social exchange between two groups of lactating primiparous heifers on milk production, dominance order, behavior and	Hasegawa *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	1997	dairy heifers	Angular dominance value (ADV) (Beilharz *et al.*, 1966; Beilharz and Zeeb, 1982)

adrenocortical response					
Influence of feeding operation and social factors on cattle locomotion in free stall barns	Uetake *et al.*	CANADIAN JOURNAL OF ANIMAL SCIENCE	1998	dairy calves	Social rank according to Kondo and Hurnik (1990)
Competition for total mixed diets fed for ad libitum intake using one or four cows per feeding station	Olofsson	JOURNAL OF DAIRY SCIENCE	1999	dairy cows	Dominance value (DV) (Sambraus, 1975)
Competition for total mixed diets fed restrictively using one or four cows per feeding station	Olofsson, J.; Wiktorsson, H.	ACTA AGRICULTURAE SCANDINAVICA SECTION A-ANIMAL SCIENCE	2001	dairy cows	Dominance value (DV) (Sambraus, 1975)
The effects of social dominance on the production and behavior of grazing dairy cows offered forage supplements	Phillips, C.J.C.; Rind, M.I.	JOURNAL OF DAIRY SCIENCE	2002	dairy cows	The ratio of wins to losses in each encounter was transformed to a normal distribution (Beilharz and Mylrea, 1963)
Individual differences in behaviour and in adrenocortical activity in beef-suckler cows	Mulleder *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2003	beef cows	Dominance value (DV) (Sambraus, 1975)
Frequency of feed delivery affects the behavior of lactating dairy cows	DeVries *et al.* .	JOURNAL OF DAIRY SCIENCE	2005	dairy cows	Not detailed
Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle	Huzzey *et al.*	JOURNAL OF DAIRY SCIENCE	2006	dairy cows	Index of success (Mendl *et al.*, 1992; DeVries *et al.*, 2004)
The effects of restricted feed access and social rank on feeding behavior, ruminating and intake for cows managed in automated milking systems	Melin *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2007	dairy cows	Dominance value (DV: high social rank ($0.55 \leq DV \leq 0.75$) or low social rank ($0.20 \leq DV \leq 0.55$) (Olofsson *et al.*, 2000)
Effect of the number of concentrate feeding places per pen on performance, behavior, and welfare indicators of Friesian calves during the first month after arrival at the feedlot	Gonzalez *et al.*	JOURNAL OF ANIMAL SCIENCE	2008	dairy calves	Angular dominance value (ADV) (Beilharz and Zeeb, 1982)
Short communication: Dominance in free-stall-housed dairy cattle is dependent upon resource	Val-Laillet *et al.*	JOURNAL OF DAIRY SCIENCE	2008	dairy cows	Dominance index from 0 to 1; all animals into 3 subgroups of dominance (Galindo and Broom, 2000): high-ranking

					animals (index ≥0.6), middle-ranking animals (0.4 ≤ index < 0.6), and low-ranking animals (index <0.4)
The concept of social dominance and the social distribution of feeding-related displacements between cows	Val-Laillet *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2008	dairy cows	Dominance rank order was calculated using a software program: MatMan (Noldus Information Technology1, Wageningen, The Netherlands) (DeVries, 1998)
Impact of agonistic interactions on feeding behaviours when beef heifers are fed in a competitive feeding environment	Zobel *et al.*	LIVESTOCK SCIENCE	2011	beef heifers	Successful feeding events based on physical and non-physical interactions instead of assign a rank based on physical interactions. Avoided classifying animals as "dominant" or "subordinate" which allowed to describe how the level of competition in which an animal was involved corresponded to its feeding behaviour at different times of the day
Effects of social dominance, water trough location and shade availability on drinking behaviour of cows on pasture	Coimbra *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2012	dairy cows	Dominance value (DV) (Kondo and Hurnik, 1990)
Short communication: Relationship between competitive success during displacements at an overstocked feed bunk and measures of physiology and behavior in Holstein dairy cattle	Huzzey *et al.*	JOURNAL OF DAIRY SCIENCE	2012	dairy cows	Competition index (CInd) (Val-Laillet *et al.*, 2008; Galindo and Broom, 2000): low success (LS: CInd <0.40), medium success (MS: 0.40 < CInd ≤0.60), and high success (HS: CInd >0.60)
Application of pre-partum feeding and social behaviour in predicting risk of developing metritis in crossbred cows	Patbandha *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2012	dairy cows	Displacement index (DI) (Galindo and Broom, 2000). The cow having lower displacement index value was considered as lower social rank or subordinate
Dairy cow feeding space requirements assessed in a	Rioja-Lang *et al.*	JOURNAL OF DAIRY SCIENCE	2012	dairy cows	Index of success / method described by Mendl *et al.*

Y-maze choice test					(1992)
Space allowance and barriers influence cow competition for mixed rations fed on a feed-pad between bouts of grazing	Arachchige *et al.*	JOURNAL OF DAIRY SCIENCE	2014	dairy cows	Index of success (Mendl *et al*., 1992; DeVries *et al*., 2004)
Effect of stocking density on social, feeding, and lying behavior of prepartum dairy animals	Lobeck-Luchterhand *et al*..	JOURNAL OF DAIRY SCIENCE	2015	dairy cows	Displacement index (DI) (Galindo & Broom, 2000). Animals with a DI >0.6 were classified as high ranking, 0.4 to 0.6 were middle ranking, and animals with a DI <0.4 classified as low ranking
Factors influencing the priority of access to food and their effects on the carcass traits for Japanese Black (Wagyu) cattle	Takanishi *et al*.	ANIMAL	2015	beef calves	Social rank determined according to the priority of access to food instead of social dominant indexes (Langbein and Puppe, 2004)
Relationship between quantitative measures of temperament and other observed behaviors in growing cattle	Bruno *et al.*	APPLIED ANIMAL BEHAVIOUR SCIENCE	2018	beef steers	Two dominance indices (Hemelrijk *et al*., 2005): average dominance index (ADI) and David's score (DS)

4.4 Discussion

To assess studies specifically emphasizing the relation between the social hierarchy of cattle and its relation to feeding behaviour, we reviewed 418 articles in full regarding the search strings. From all, 26 articles were specifically considered for this systematic review. The studies showed great variability regarding the study design (mixing or separating groups, increasing or decreasing stocking density or space allowance, altering the frequency of feed delivery, using or not feed barriers, restricting access to feeding area). Only one of the studies was performed with cattle raised under rotational grazing system (Voisin's grazing system). Cattle on their natural environment (pasture) show a social hierarchy that organize them as a group, including the use of the available resources. However, when confined the number of interactions is higher (TRESOLDI *et al*., 2015). Indeed, most research efforts are towards confined or semi-confined cattle.

Another point that greatly varied between the articles was the method of determination of the social hierarchy or social rank. According to the selected articles, the social rank determination was mainly related to the occurrence of agonistic interactions, with or without physical contact or total displacement of an animal from the feeding area while feeding. Among the most commonly used methods are: the index of success (MENDL *et al*., 1992), the dominance value (SAMBRAUS, 1975; KONDO & HURNIK, 1990; OLOFSSON *et al*., 2000), the angular dominance value (BEILHARZ & ZEEB, 1982) and the competition or displacement index (GALINDO & BROOM, 2000).

Only three studies did not used one of the methods listed above. Val-Laillet *et al*. (2008) scored displacements (with physical contact) at the feed bunk and calculated the dominance rank order using the MatMan software program, which is based on the procedure developed by DeVries (1998). Then, they calculated three indices and evaluated the discriminative power of each: *Galindo–Broom Index* (based on the proportion of displacements an animal initiated compared to the total number of displacements in which the animal was involved, either as an initiator and a receiver); *Mendl Index* (based on agonistic interactions; in this index, only one displacement is sufficient to say that a cow is able to displace another cow) and the *Kondo–Hurnik Index* (specifically developed for dairy cows; related to the number of displacements initiated and received between all possible pair of animals within a group).

In their study, Zobel *et al*. (2011) did not assign a rank based only on physical interactions as they wanted to avoid classifying the animals as “dominant” or “subordinate” and so they could describe how the level of competition in which an animal was involved corresponded to its feeding behaviour at different times of the day. They established a count of successful feeding events in which the animals successfully gained access, defended and maintained their eating position.

The study of Takanishi *et al*. (2015) also did not assigned a dominance status to the animals; the social rank was determined according to the priority of access to food instead of the ordinary measurements such as social dominant indexes (LANGBEIN & PUPPE, 2004). The farm manager observed the animals behaviour and recorded the ranking for the priority of access to food, assigning first rank for

those animals who feed first. The decisions of not using regular indexes and particularly to ask the farm managers to observe the animals and to allocate them to the different social ranks, is in part a good strategy to gain time and increase the number of farms and animals involved on the research; but on the other hand, it is a risky strategy as, even with adequate training, it is difficult to assure intra and inter-observer reliability. Moreover, the accuracy of the observations may be jeopardize, once there is psychological involvement of the farmer with their cows.

According to the study of Val-Laillet *et al*. (2008), who compared different indexes to estimate social hierarchy, the Galindo–Broom Index (GALINDO & BROMM, 2000) estimates how good an individual is at frequently displacing others without being displaced frequently. The index proposed by Mendl *et al*. (1992) evaluates how good an individual is at being able to displace others at least once without being displaced. And the index developed by Kondo & Hurnik (1990) assesses how good an individual is at being dominant in dyadic interactions. According to the authors, the three indices were all highly intercorrelated and were also correlated with the DeVries (1998) ranking method. However, despite numerous similarities and strong correlations between the indices, there are subtle differences that can affect the ranking outcomes and also it may be a research bias on the studied variable, eg time eating.

Regardless of the method used to determine the social hierarchy, the studies showed results about different aspects of the influence of the social hierarchy on the feeding behaviour of cattle. At high stocking densities, cows with lower indices of success or subdominants are displaced more often by dominant animals (OLOFSSON & WIKTORSSON, 2001), even with the post-and-rail barrier design (HUZZEY *et al*., 2006). However they were not displaced as frequently when fed more often (DeVRIES & von KEYSERLINGK, 2005). Regarding feeding space, when this is 0.3 and 0.45m with the dominant cow present, the subordinate cows chose to feed alone, instead of close to a dominant. Once the space allowance exceeds 0.45 m, subordinate cows show no preference (RIOJA-LANG *et al*. 2012).

Cows in the high-ranking group spent a greater percentage of their time at the feeder compared to low ranking cows (VAL-LAILLET

et al., 2008). Dominant cows showed higher eating rate (LEAVER & YARROW, 1980), higher feeding time and longer mean feeding bout duration than subordinate ones. When more space is allowed at the feeding place and feed barriers are present, subordinate cows could increase their feeding time percentage (HETTI ARACHCHIGE *et al*., 2014). Dominant and subordinate cows kept together had the same grazing time according to the study of Phillips & Rind (2002), but subordinate cows had longer hay feeding time and increased weight gain compared to dominant cows. Dominance was also positive related to the time spent eating concentrate (GONZALEZ *et al*., 2008) and the time spent chewing, i.e., high rank cows chewed for longer while low rank cows chewed faster (MELIN *et al*., 2007). On the other side, Lobeck-Luchterhand *et al*. (2015) and KetelaardeLauwere *et al*. (1996) did not find relation between the the dominance value and the time spent feeding.

All these studies considered the effects of social dominance related to feeding behaviour, but it is important to point out that for dairy cows, the dominance is not consistent across three different available resources: feed bunk, free stall and mechanical brush (VAL-LAILLET *et al*. 2008). Motivation, related to cow's physiological state, also plays an important role on the dispute for resources (HÖTZEL *et al*., 2003).

Beyond motivation, there seem to be different behavioural strategies adopted by the animals to cope with their social environment and gain access to what they want, across situations of low and high social competition (MULLEDER *et al*., 2003). According to Olofsson (1999) when the competition level increased, cows of low social rank tended to adjust behaviours to a greater extent than did the more dominant cows and instead of eating, the subordinate cows were observed standing and lying to a greater extent around the two milkings. Cows with low dominance values adapt their visits to the automatic milking system and to the feeding gate by visiting both parts of the cowshed more at quiet times (KETELAARDELAUWERE *et al*., 1996). Avoidance and affiliative interactions are also strategies adopted by non agonistic animals to appease higher ranking animals (MULLEDER *et al*., 2003).

Despite all the possible strategies developed and used by the animals, some management practices that disturb social stability in herds should be avoided (HASEGAWA *et al*., 1997) and It is also necessary to improve the actual management systems to reduce competition at the feeder (VAL-LAILLET *et al*., 2008b). For example, the waiting area of automatic milking systems should be designed to prevent cows with lower dominance values from being subjected to severe aggression from higher ranking cows (KETELAARDELAUWERE *et al*., 1996). Another example is the existence of a simple bar at the feed trough, protecting the animals head, which gives the "notion of protection" and improves the total time that subordinate animals access the feed (BOUISSOU, 1970).

The equality of access to important resources between different categories of animals was addressed by VAL-LAILLET *et al*. (2008a). Equality might be achieved by different strategies as avoiding overstock at the feed bunk (HUZZEY *et al*., 2006), the use of feed barriers or a higher space allowance that would increase the motivation of low ranking cows to access fresh feed and improve their nutritional status (HETTI ARACHCHIGE *et al*., 2014; RIOJA-LANG *et al*., 2012). The access to fresh feed for all cows may also be improved by increasing the frequency of feed delivery, potentially reducing variation in diet quality intake (DeVRIES & von KEYSERLINGK, 2005).

4.5 Conclusions

The reviewed studies showed a great variability in study designs and outcomes. Our analyses highlighted some aspects that influence the effects of social hierarchy on the access to feed resources, as the frequency of feed delivery, the access to the feeding area, group size or space allowance, quantity or quality of food troughs and even motivation or physiological state. All selected studies have shown consequences of this relation for the animals such as decreased dry matter intake and lower weight gain; high level of agonistic encounters (fights) and cortisol, as well as changes in normal animal behaviour. The different strategies used by cattle pointed out by the authors also lead to an understanding that the low rank animals are not necessarily worst in terms of coping and performance compared to high ranking animals. What is clear in all studies' conclusions is that the social dominance does affect feeding behaviour of cattle, with more or less

consequences according to the management practices. More research is needed for a better understanding of how to mitigate possible negative effects of social dominance, as well as publicizing the results to farm managers to really make a difference on rearing systems regarding to animal behaviour.

4.6 References - at the end of document

5. Study 2

Social hierarchy and feed supplementation of heifers: line or piles?

Abstract

Cattle on pasture may have unequal access to grain supplement due to the effect of social dominance. Subordinate animals are known to have less access to resources when a competition exists. This trial was designed to test if distributing feed supplement (corn meal) along and under the fence in individual piles would affect heifers feeding behaviour and grant better access to all animals compared to supplement offer in a continuous line. Four groups of nine heifers were used in a 2 × 2 cross-over design, and tested in two treatments: LINE (1 linear meter/animal) and PILE (one pile/heifer distant 1 meter from each other). Each period had three days for habituation followed by seven days for data collection. Animals were managed under Voisin's rational grazing system and observed for one hour from the moment they entered the new paddock (8am to 9am). A one-minute interval instantaneous scan sampling of each heifer was taken and their behavioural states registered as: grazing, eating grain supplement, disputing or other. All agonistic interactions were recorded and a sociometric matrix was calculated for each group and then every heifer was defined as dominant, intermediate or subordinate. Treatment did not affect feeding behaviour but there was an effect of social hierarchy status. High and intermediate ranking heifers spent more time eating supplement than low ranking ones ($P \leq 0.03$). Subordinate heifers grazed longer than intermediate, which in turn grazed longer than dominant heifers ($P \leq 0.01$). Social rank did not affect disputing behaviour, but there was a trend for more disputing events when concentrate was distributed in piles ($P = 0.09$). Dominance score was associated with initial body weight ($r= 0.686$; $P \leq 0.0001$). In summary, distributing the grain supplement in individual piles did not benefit the subordinate heifers as they had less access to the supplement than the dominant ones. When entering a new paddock with supplement offer, the subordinate heifers seemed to avoid competing for grain and spent

more time grazing while the dominant ones spent more time eating supplement.

Keywords: Cattle. Dominance. Rotative grazing. Feeding behaviour.

5.1 Introduction

Cattle are social animals and organize themselves in hierarchies according to their motivation and ability to fight for resources (FRIEND & POLAN, 1974; PHILLIPS & RIND, 2002). According to Beilharz & Zeeb (1982) "dominance exists when the behaviour of one individual is inhibited by the presence or threat of another"; therefore, the dominance relationships may affect several behaviours and may function as a common good rather than mainly serving the advantage of the high-ranking individuals (SAROVÁ *et al*., 2017).

In grazing conditions, social herbivores interfere with each other and increase the aggressive interactions, either to acquire a resource or to defend it against conspecifics (KIDJO *et al*., 2016), resulting in dominant individuals acquiring certain advantages (like access to better quality and/or quantity of food) over subordinates when competition exists, and specially when resources are scarce, as shown in buffaloes (MADELLA-OLIVEIRA *et al*., 2012), red deers (APPLEBY, 1980; THOULESS, 1990), wild woodland caribou (BARRETTE & VANDAL, 1986), and goats (BARROSO *et al*., 2000). Dominance interactions also affect the access of cattle to food in feeders (VAL-LAILLET *et al*., 2008; PROUDFOOT *et al*., 2009) and play an important role in supplement consumption by beef cattle: the older and more dominant animals typically consume more supplement and prevent younger and subordinate animals from consuming required levels (BOWMAN & SOWELL, 2002).

Studies focusing on intensively housed dairy cattle have shown that a large number of physical agonistic interactions take place at the feeder, particularly when competition levels are high (DeVRIES & von KEYSERLINGK, 2005; HUZZEY *et al*., 2006; VAL-LAILLET *et al*., 2009). With a higher animal density there is higher number of agonistic interactions per animal (TRESOLDI *et al*., 2015). Some researchers assume that the feeding area does not need to accommodate all animals at the same time if they are able to consume sufficient amounts of food

in 24-h periods. However, at certain times of day, access to the feed has a high motivational value (DREWS, 1993) and, as dairy cows live within a hierarchical social structure, dominant animals can monopolize resources (RIOJA-LANG *et al*., 2012) and prevent other animals from accessing it. This may lead to a deviation from the targeted supplement intake per animal that can negatively impact animal production (BOWMAN & SOWELL, 1997).

Altering feeder design and supplement delivery methods may change dominance patterns and improve the effectiveness of supplementation programs (BOWMAN & SOWELL, 1997). For competitively fed cows, when the frequency of the feed delivery is increased from 2 to 6 times a day it may improve access to feed bunk and provide the opportunity for more cows to feed during peak periods (CROSSLEY, 2018). The fence line feeding, or strap feeding, is designed to allow all cows to feed at the same time and is also the most common method used in free-stall dairies (RIOJA-LANG *et al*., 2012).

In grazing systems, an adequate space per animal is often assured and the priority of access to the best pasture and water may form the basis of the herd hierarchy, which can explain why dominant cows have sometimes been found to produce more milk than subordinate cows (VAL-LAILLET *et al*., 2008; SOLTYSIAK & NOGALSKI, 2010). On grazing behaviour, there is an optimum inter-individual distance for grazing animals, determined mainly by group size; however, subordinate animals can graze away from the herd, but this motivation would be counter-acted by the cohesive forces that encourage them to stay together for protection (RIND & PHILLIPS, 1999). Sato (1982) analysed leadership during grazing in a herd of cattle and found that low rank heifers showed tendencies to be more independent from the rest of the herd, grazing away from other cattle and being found further from the nearest neighbour than the mean distance among the other heifers. For Sarová *et al*. (2010), the dominant cows are free to go where they wish while the subordinates need, to a certain extent, to avoid them and follow them.

So, as social dominance affects cattle feeding behaviour this is of practical importance if these interactions result in certain animals consistently missing out on access to important resources. Considering that cattle on pasture receiving grain supplement may have unequal access to supplement due to the effect of social hierarchy, we hypothesized that when grain supplement is offered in individual piles

the subordinate animals can benefit from it by getting better access to feed supplementation than when offered in line. This study was designed to evaluate if distributing the supplement along the fence in individual piles would affect heifers feeding behaviour and grant better access to all individuals in the group, specially subordinate ones, compared to supplement in continuous line.

5.2 Materials and methods

The study was undertaken between July and August of 2015 (winter) at the Voisin's Rational Grazing System (VRG) unit of the Federal University of Santa Catarina Experimental Farm of Ressacada, Florianópolis, Brazil (17°40'25" S; 48°32'30" W). The study was performed in accordance to the Ethic Committee on Animal Use of the Federal University of Santa Catarina (CEUA/UFSC) under the approved protocol number 1004100516.

The animals are routinely raised on a 21 ha pasture, mainly composed by plants of the genus Axonopus, Paspalum, Brachiaria, Pennisetum, Melinus, Setaria, Cynodon, Panicum, Hemarthria, Desmodium, Trifolium, Lotus, Arachis, Stylosanthes, Lolium. The pasture is divided in 84 paddocks averaging 2500m2 under a VRG management system. Animals were daily moved to a new paddock, with mineral salt and water *ad libitum*. Water was available in a round water trough made of Polythene (120 cm diameter and 60 cm high and 500 L capacity; Tigre®, Joinville, SC, Brazil). For the experimental period, some paddocks were further divided in parcels of 620m² each.

5.2.1 Animals, treatments and experimental design

Four groups of nine heifers were used in a 2 × 2 cross-over design, testing two treatments. All heifers were non-pregnant (15 Braford, 15 Jersey, 4 Holstein, and 2 Jersey × Holstein), with an average age of 20 months old and weighing 212.5 ± 39.33 kg. Heifers were grouped by breed and body weight and then randomly distributed to one of the four groups. Animals were identified by ear tag numbers and individually marked with numbers on their bodies with black and green livestock markers (Raidex®, Dettingen; Erms Germany).

The four groups were tested in two ways of distributing corn meal along and under the fence (treatments): one continuous line (LINE;

1 linear meter/animal) or 9 individual piles (PILE; one pile/heifer distant 1 meter from each other). The amount of 1 Kg of supplement/animal was distributed every morning, immediately before heifers entered the new paddock. Each group was tested in both treatments, for 10-day periods (3 days for habituation followed by 7 days for observations and data collection, with 3 days for observation of agonistic interactions and 4 for general behaviours).

5.2.2 Measurements

5.2.2.1 Determination of social rank

During the first three days of data collection in each period, from 8 to 9 am, all agonistic interactions (instigator-victim), with or without physical contact resulting in the physical displacement of an animal were simultaneously recorded in the four groups (HURNIK *et al*., 1995) by four trained observers, who switched groups within and between periods. Then, a dominance index was calculated according to Kondo & Hurnik (1990). An "S" value was calculated for each heifer in relation to every other one, so if the animal "I" beat the animal "J" in Xij interactions, and an animal "J" beat an animal "I" in Xji interactions, Sij corresponds to:

$$Sij = \frac{Xij - Xji}{|Xij - Xji|}$$

and it always results a value of -1 or 1 (0 when tie). Then, the dominance index for heifer "I" (Si) is the sum of the S that animal had in each dyad. The dominance value for each individual was calculated as a result of the sum of all relationships of each animal with each other animal within the group. When two or more animals had the same "S" value (for example: animal 17= animal 36), the tiebreaker was the result of direct confrontation within both animals, and if necessary, the aggressiveness index for each heifer was a second tiebreaker.

A dominance scale was constructed for each group, based on the difference between the maximum and minimum dominance value (Table 3). This was divided in three social categories, the dominants (D) in the upper stratum, intermediates (I) in the middle and subordinates (S) in the lower stratum of the scale.

Table 3. Dominance score and respective social hierarchy of each individual animal within each group.

Group	Animal	Dominance Score	Social hierarchy	Group	Animal	Dominance Score	Social hierarchy
1	1	-2	I	3	19	4	D
	2	2	I		20	8	D
	3	6	D		21	2	I
	4	3	D		22	6	D
	5	-5	S		23	-3	S
	6	-8	S		24	-8	S
	7	2	I		25	-6	S
	8	6	D		26	0	I
	9	-4	S		27	-3	I
2	10	4	D	4	28	6	D
	11	6	D		29	0	I
	12	2	I		30	4	D
	13	-2	I		31	4	I
	14	-4	S		32	-6	S
	15	-7	S		33	-4	S
	16	4	D		34	-8	S
	17	-2	S		35	6	D
	18	-1	I		36	-2	I

5.2.2.2 Heifers behaviour during supplementation

The behaviours eating supplement (defined as animal eating grain supplement, with head down on the fenceline and mouth on the supplement or above it while chewing), grazing (defined as animal grazing, with head down and the mouth below or at the level of the forage making movements of forage prehension or grabbing forage; stationary or moving forward to new grazing patches), disputing (defined as animal contesting with another for grain, pasture or other), and others (defined as animal performing any other activity than eating concentrate, grazing, disputing, being either standing or lying) were directly recorded by scan sampling during 1h (8 to 9 am) on the last 4 days of each period. Scan samples were taken for each heifer every 1 minute, which yielded a total of 240 scan samples per heifer. All observations were made by four trained observers, who switched groups within and between periods.

5.2.3. Statistical analysis

Descriptive statistics were calculated using Microsoft® Excel® for Windows and all other statistical analyses were conducted using in SAS 9.3. The first 3 days of each period were considered as an adaptation period to the types of distribution of supplement along the fence (LINE vs. PILE). The frequency of behaviours was summarized over the 4 days per period yielding one value for each animal per period. The Shapiro test was used on the model residual information as well as the examination of the normal plot to evaluate the dataset for normal distribution.

The effect of treatment and social rank on the frequency of eating supplement, and grazing behaviours was analysed using mixed procedures (Proc Mixed of SAS). Treatment and social rank were included in the model as fixed effect and period as random effects. The effect of treatment and social rank on the frequency of disputing and other behaviours was analysed using generalized linear mixed models (Proc Glimmix of SAS). Treatment and social rank were included in the model as fixed effect, period as random effects and gamma as the type

of distribution. For all models animal within group was considered as experimental unit. Interactions between treatment and social rank were removed from all models as they were not significant ($P > 0.10$). Results of eating supplement and grazing behaviours are reported as least square means ± standard error (S.E.); results of disputing and other behaviours are reported as least square means (95% confidence interval). Finally, Spearman correlation was used to analyse the relationship between dominance score and initial body weight. Statistical differences are reported with the respective p value.

5.3 Results

Unlike our initial hypothesis, there was no difference on supplement access when grain supplement was offered in individual piles, compared to in line. There was, however, an effect of social hierarchy status, regardless of the way the supplement was offered. High and intermediate ranking heifers spent more time eating supplement than low ranking ones ($P \leq 0.03$). Subordinate heifers grazed longer than intermediate, which in turn grazed longer than dominant heifers ($P \leq 0.01$). Social rank did not affect disputing behaviour, but there was a trend for more disputing events when concentrate was distributed in piles ($P = 0.09$). Subordinate heifers spent more time in “others” behaviours than dominant ones ($P \leq 0.01$). Results are summarized in Table 4. Dominance score was associated with initial body weight ($r= 0.686$; $P \leq 0.0001$).

Table 4. Effect of treatment (LINE vs. PILE) and social rank (dominant, intermediates and subordinates) on eating supplement, grazing and disputing behaviours. (Normal data: least square mean ± standard error; non-normal data: least square mean (95% confidence interval).

Behaviours	LINE	PILE	p-value	Dominant	Intermediate	Subordinate	p-value
Eating supplement (%)	10.0 ± 0.5	9.2 ± 0.5	0.18	10.5 ± 0.7[a]	10.3 ± 0.7[a]	8.0 ± 0.7[b]	0.03
Grazing (%)	84.3 ± 0.7	84.9 ± 0.7	0.45	81.3 ± 1.0[a]	84.5 ± 1.0[b]	87.8 ± 1.0[c]	<0.001
Disputing (%)	1.1 ± 0.2	1.8 ± 0.3	0.09	1.3 ± 0.4	1.3 ± 0.3	1.3 ± 0.3	0.56
Others (%)	4.4 ± 0.5	3.9 ± 0.4	0.40	6.1 ± 1 [a]	4.0 ± 0.6 [ab]	2.9 ± 0.5 [b]	0.01

5.4 Discussion

Distributing the grain supplement along the fence in a continuous line may reduce disputing behaviour, but didn't significantly affect the heifers' behaviours regarding access to concentrate. Notwithstanding, subordinate animals spent more time grazing instead of competing for supplement when entering into a new paddock (APPENDIX 1.1). The fact that subordinate heifers were observed grazing more often than dominant ones supports the idea that there are differences on time budget between dominant and subordinate cows, as feeding time (PROUDFOOT *et al*., 2009; CEACERO *et al*., 2012; LLONCH *et al*., 2018) and especially grazing and lying down, when a supplement is offered (PHILLIPS & RIND, 2002). Dominant grazing dairy cows showed a higher bite and chewing rate than subordinate cows either for

pasture or silage consumption. They also had a higher milk production (PHILLIPS & RIND, 2002).

Beilharz and Zeeb (1982) suggested that hunger could provide sufficient motivation for animals to occasionally displace others of a higher rank. However, in our study this did not happen; when the heifers entered a new paddock with fresh pasture and supplemental feed just delivered, the low rank animals preferred to graze instead of getting into a fight for grain supplementation. As the animals stay typically 24h in each paddock, it is possible that if the supplement was offered in a different time of the day, or if the heifers were pregnant or lactating, their motivation to access feed would be different and the results may be different.

In groups of social animals, the low rank ones may evade conflicts or show the ability to resist to some agonistic contacts as a mechanism to increase the time spent feeding, compared to high and mid ranking ones (KIDJO *et al*., 2016). It is likely that subordinate animals prefer to avoid fights with dominants individuals and, therefore, giving up competing for supplementation if there is an opportunity to obtain good quality feed from another source, like fresh pasture, as it happened in our study. Moreover, pasture composition and nutrient supply can affect feeding behaviour (GREGORINI, 2012), and cattle has the ability of selective grazing according to their needs (MACHADO FILHO *et al*., 2014).

The low rank heifers were found seeking for supplementation only after all high rank ones had left the feed offer location, when there was almost no grain left. Similar result was found by Bruno *et al*. (2017), who found that low ranking animals "waited their turn" during feeding, approaching the feed bunk only after other animals had left. This may explain the higher occurrence of others behaviour among subordinate than dominant heifers in this study. It is possible that subordinate heifers develop different strategies according to how they predict that other individuals in the herd may influence themselves (SOWELL *et al*. 2000). In competitive environments, dairy cattle are able to modify their feeding rate in response to competitive pressure (PROUDFOOT *et al*., 2009) and increase feed intake when there is higher competition for feed access (HOSSEINKHANI *et al*., 2008; PHILLIPS & RIND, 2002; CROSSLEY *et al*., 2017). Greter *et al*.,

(2013) found that heifers fed once a day were more competitive than those fed twice a day, with more heifers at the feed bunk immediately following feed delivery when fed 1×/d but not when fed 2×/d.

This provides evidence that animals are able to use multiple strategies to ensure adequate access to a resource, in the case of feed consumption. But when some animals are unable to adapt to a competitive environment they may be at a disadvantage in terms of the quantity and quality of the feed to which they have access (ZOBEL *et al*., 2011). It is likely that low ranking animals walk away, trying to feed away from the high ranking ones (MANSON & APPLEBY, 1990). It has also been observed that the dominant animals profit from priorities in the choice of the best places for eating or resting as they select with more intensity the most preferred areas (DiVIRGILIO & MORALES, 2016) and even when they are no longer hungry they may temporarily forbid access to the dominated animals to the food (BOUISSOU, 1980) or water (COIMBRA *et al*., 2012).

Breed was associated to social rank and Braford heifers were dominant over Jersey and over Holstein. A few studies have also demonstrated associations between breed and social hierarchy, as Angus over Shorthorns and of Shorthorns over Herefords (WAGNON *et al*., 1966), or Angus over Herefords (despite being lighter in weight) (STRICKLIN, 1983). Brakel and Leis (1976) introduced cows into established herds of different breeds and found a breed ranking of Brown Swiss over Holstein over Guernsey over Jersey. As we were expecting this breed-dominance relation to be found, we did block the groups according to breed and weight, so that this should not negatively affect the results of the study.

Another point to consider is the feeding space per heifer and its relation with social dominance. According to Bouissou (1980), food is often supplied as a rapidly consumed concentrate on a given area and period, which is totally different from what normally happens to herbivorous animals. So, it leads to considerable competition and favours aggressive reactions. Moreover, if the number of animals exceeds the number of places available at the feeding trough, some, and often the same individuals, consume their food later and consequently eat the foodstuffs left by the first animals. In this study we provided 1 linear meter per animal during supplementation time or one pile per

heifer distant 1 m from one another, based on studies that have shown that increasing the feeding space from 0.5 to 1m (DeVRIES *et al*., 2004) or from 0.6 to 1.0 m (HETTI ARACHCHIGE *et al*, 2014) reduces competition and aggressive interactions and improves cow feeding behaviour, with the effects being greatest for subordinate cows. With this amount of feeding space, up to 70% of cows in a group may eat simultaneously (DeVRIES *et al*., 2004).

In our study, subordinate heifers were grazing while dominant heifers were eating supplement, most likely because low-status cows prefer to feed alone than next to a dominant animal (RIOJA-LANG *et al*., 2012) than as a result of limited space allowance as explained above.

This study has shown that social hierarchy affects the behaviour of grazing heifers receiving grain supplement more than the way the supplement is offered. Dominant heifers spend more time eating supplement than subordinate ones. Unlike the majority of the published studies about social hierarchy and feeding behaviour, which have been carried out with housed animals or with restricted access to pasture, our study was carried out with animals intensively managed on pasture, and even then, the effects of the heifers social behaviour were evident. Regardless of the kind of the rearing system, it is very important to consider the group formation and the access to feed resources to minimize the social dominance effects and to promote better management practices concerning farm animal behaviour.

5.5 Conclusions

This study shows that distributing the grain supplement in individual piles under the fence, compared to distributing it in line under the fence, did not benefit the subordinate heifers regarding their access to the supplement. When entering a new paddock with supplement offer, the subordinate heifers seemed to avoid competing for grain and spent more time grazing while the dominant ones spent more time eating supplement.

5.6 References - at the end of document

6. Study 3

Time of supplementation and social dominance influence feeding behaviour of heifers on Voisin's grazing system

Abstract

Social hierarchy affects the access of animals to feed resources. On Voisin's rational grazing systems, "on pasture" supplementation time may influence feeding behaviour. If supplement is offered when pasture is available in good quality, then subordinate heifers may have the choice to access better grazing sites instead of competing for grain. Thus, this trial was designed to test different delivery times of grain supplement on feeding behaviour of heifers. Thirty-four non-pregnant heifers were divided in two groups (group 1: n=15; group 2: n=19) and tested in a cross-over design with two treatments: AM: supplement provided at 8am - time to enter the new paddock; PM: supplement provided at 4pm - 8 hours after paddock entry. Supplement was offered under the fence, on the ground, on a basis of 2kg/heifer/day, allowing 1m/animal. Animals were moved to a new paddock every morning, with drinking water and mineral salt offered *ad libitum*. The experimental period had 7 days for habituation followed by two periods of 35 days each for data collection. Behaviours were observed for 2 hours from the moment the supplement was delivered according to treatment (from 8-10am and 4-6pm). Scan sampling with two-minutes interval was used to register heifers' behaviour: grazing along the paddock, grazing near the fence, eating supplement and other. All agonistic interactions were recorded (instigator-victim), and a sociometric matrix was calculated for each group. Within each group, animals were classified as dominant, intermediate and subordinate, according to social rank. Once a week pasture samples were collected according to the handplucking technique to determination of crude protein and fiber content. Statistical analysis included Proc Mixed and Glimmix of SAS for the effect of treatment and social rank on the observed behaviours. Heifers spent more time grazing on the AM treatment ($p<0.0001$) and performed other behaviours more in the PM

treatment ($p<0.0001$). Dominant animals spent more time eating supplement than subordinate ones ($p=0.0008$), which in turn spent more time grazing along the paddock ($p=0.0067$) but not along the fence ($p=0.0008$). Crude protein content of pasture samples was higher in the AM treatment ($p<0.0001$). There was an interaction between the order to leave the feeding area, social rank and crude protein of consumed diet ($P = 0.04$). In Voisin's rational grazing system it is better to offer grain supplement when the animals get into a new paddock. Subordinate heifers can choose to graze best quality patches while the dominant heifers deal to eat grain supplement instead of graze along the paddock and prevent the other animals of selecting the best feeding sites.

Keywords: Social hierarchy. Cattle. Feed Resources.

6.1 Introduction

The rotational grazing system proposed by Voisin is a sustainable alternative for grazing cattle and it assure that the animals graze the forages at their best, as long as the animals stay in the paddock for no longer than 3 days (maximum yields occur if animals stay for only one day) and that there is sufficient interval between two successive shearings so they do not graze the regrowth (VOISIN, 1974). Despite the benefits of the rotational grazing, the farmers may need to offer feed supplementation to the animals, as a nutritional increment in times of pasture scarcity or as being a constant part of the diet of high production animals.

Supplementation at specific times of the day not only may supply the ruminant animal with the appropriate concentration of energy and protein substrates, but also may alter their grazing patterns (SCAGLIA *et al*., 2009). Despite widespread use of dietary supplements, technical recommendations to farmers target a regular daily supply of food to maximize weight gain or increase milk production. However it mainly consider aspects such as animal category, nutritional requirements, stage of pastures and costs of the supplements, without taking into consideration the social behaviour of the animals and its consequences on the access to resources.

Cattle are social animals and organize themselves into hierarchies according to their willingness and ability to fight for resources (PHILIPS & RIND, 2002). The social hierarchy affects the access to resources and the dominant animals are known to have priority of access to resources (SAROVA *et al*., 2010, PHILLIPS & RIND, 2002; ANDERSSON *et al*., 1984), specially when resources are limited (PHILLIPS, 1993). Social hierarchy thus affects drinking (COIMBRA *et al*., 2012) and feeding behaviour (BARROSO *et al*., 2000).

Besides that, the grazing behaviour may be related to diurnal changes in food quality (PROVENZA *et al*., 1998). The circadian rhythm of forage increases soluble sugar concentrations during the day and it may explain why herbivores show a strong preference for afternoon than morning harvested forage (MARYLAND *et al*., 2005). When instantaneous stocking rate is increased, there is more competition for food (BOISSY, 1999) and the forage availability per animal is reduced so as the animals selectivity. In rotationally grazed paddocks, sward structure changes continually as grazing proceeds along the day and so, changes in quantity and quality associated with the depletion of the sward have a detrimental effect on bite mass and intake rate (McGILLOWAY *et al*., 1998).

Therefore, if the dominant animals have the priority on the use of resources, how do the subordinate animals behave in such conditions? Are there strategies used both by the animals or the farmers to mitigate the negative effects of social dominance? Based on animal physiology, we assume that on a rotational grazing system, where the animals get in to a new paddock every morning, it would be logical to offer feed supplement in the late afternoon, when pasture availability is decreased and the animals are more motivated to obtain food.

However, based on cattle social dominance we hypothesized that the best time to offer feed supplement is precisely by the time when they get in to the new paddock (morning), so the subordinate animals can graze the best patches while the dominant animals eat the supplement. Thus, this study was designed to test different delivery times (morning x afternoon) of grain supplement on feeding behaviour of heifers.

6.2 Materials and methods

The study was undertaken between June and August of 2016 (winter) at the Voisin's Rational Grazing System (VRG) unit of the Federal University of Santa Catarina Experimental Farm of Ressacada, Florianópolis, Brazil (17°40'25" S; 48°32'30" W). The study was performed in accordance to the Ethic Committee on Animal Use of the Federal University of Santa Catarina (CEUA/UFSC) under the approved protocol number 1004100516.

Before the study, the animals were routinely raised without any feed supplementation on a 24 ha pasture, mainly composed by plants of the genus *Axonopus, Paspalum, Brachiaria, Pennisetum, Melinus, Setaria, Cynodon, Panicum, Hemarthria, Desmodium, Trifolium, Lotus, Arachis, Stylosanthes, Lolium.* The pasture was divided in 86 paddocks averaging 2500m2 under a Voisin's Rational Grazing system. Animals were daily moved to a new paddock, with mineral salt and water *ad libitum*.

6.2.1 Animals, treatments and experimental design

The animals were divided in 2 groups, according to breed: 15 Braford heifers (group 1) and 19 Jersey heifers (group 2). The average initial weight was 270 ± 57 Kg. Each group was moved to a new paddock everyday, according to Voisin's rational grazing system. Mineral salt and water were always available *ad libitum*. Animals were identified by ear tag numbers and individually marked with numbers on their bodies with black and green livestock markers (Raidex®, Dettingen; Erms Germany).

Each group was allocated to one of the treatments: AM: supplement was offered entered the paddock, at 8am; and PM: supplement was offered at the end of paddock occupation, at 4pm. The experimental design was a cross-over with 5 days for habituation to observers and the experimental routine followed by 2 periods of 35 days each for data collection. The supplement was a commercial ration for cattle (12%CP) and was offered on a daily basis of 2 Kg/animal/day, on the floor under the fence-line, in the morning or afternoon, according to treatment.

6.2.2 Measurements

Data collection included observations of: agonistic interactions (instigator-victim), ingestive behaviour (grazing - along the paddock or near the fence; eating supplement and other; Table 1). All the ingestive behaviour and the agonistic interactions were directly recorded by instantaneous scan sampling with 2 minutes interval (LEHNER, 1996), twice a week for 2 uninterrupted hours from the moment the supplement was offered, resulting in 20 non-consecutive days of direct visual observation (40 hours of data collected). There were 6 trained observers, who switched groups within and between periods.

Table 5. Description of behaviours observed during the study. The ethogram was based on the definitions adopted by the "Laboratório de Etologia Aplicada e Bem-estar Animal" (LETA) of the Universidade Federal de Santa Catarina, Brazil (COIMBRA *et al*., 2012).

Behaviour	Description
Grazing along the paddock	Animal grazing along the paddock, with head down and the mouth below or at the level of the forage making movements of forage apprehension or grabbing forage; stationary or moving forward to new grazing patches
Grazing near the fence	Animal grazing as described above but along the fenceline where the grain supplement was offered (feeding area)
Eating supplement	Animal eating grain supplement, with head down on the fence-line and mouth on the supplement or above it while chewing
Other	When the animal performed an activity, either standing or lying, with the exception of the behaviours described above

All agonistic interactions (instigator-victim), with or without physical contact resulting in the physical displacement of an animal were simultaneously recorded in the two groups (HURNIK *et al*., 1995). Then, a dominance index was calculated according to Kondo & Hurnik

(1990). An “S” value was calculated for each heifer in relation to every other one, so if the animal “I” beat the animal “J” in Xij interactions, and an animal “J” beat an animal “I” in Xji interactions, Sij corresponds to:

$$Sij = \frac{Xij - Xji}{|Xij - Xji|}$$

and it always results a value of -1 or 1 (0 when tie). Then, the dominance index for heifer “I” (Si) is the sum of the S that animal had in each dyad. The dominance value for each individual was calculated as a result of the sum of all relationships of each animal with each other animal within the group. When two or more animals had the same “S” value (for example: cow17=cow36), the tiebreaker was the result of direct confrontation within both animals, and if necessary, the aggressiveness index for each heifer was a second tiebreaker.

Based on Coimbra *et al*. (2012) for each group, a dominance scale was constructed based on the difference between the maximum and minimum dominance value then it was divided in three social categories, being the dominants (D) in the upper stratum, intermediates (I) in the middle and subordinates (S) in the lower stratum of the scale. Social rank of each heifer and its dominance score are shown in Table 6.

Table 6. Group, animal number (Animal), social hierarchy (SH) and dominance score (Score) of each heifer. Social rank: D for dominant, I for intermediate and S for subordinate animal.

Group 1			Group 2		
Animal	SH	Score	Animal	SH	Score
1	D	5	16	D	8
2	I	4	17	I	-2
3	S	-12	19	D	16
4	D	10	20	S	-11
5	I	0	23	I	-3
6	I	-4	24	S	-18
7	S	-6	25	I	0
8	D	13	26	S	-12
9	D	6	27	I	4
10	I	0	28	D	6
11	S	-12	29	I	2
12	I	-1	30	I	-4
13	D	8	31	D	4
14	I	-2	32	I	-6
15	S	-9	33	D	14
	-		34	D	14
	-		35	D	10
	-		36	S	-12
	-		37	S	-10

To estimate the quality of the consumed diet (crude protein, neutral and acid detergent fibre), weekly samples of ingested pasture were collected, according to the method of hand-plucking (EUCLIDES *et al*., 1992). Focal animals were selected for pasture collection, being chosen the first 3 (ORDER1) and the last 3 animals (ORDER2) that left the place of supplement supply and started grazing. Samples were taken immediately after grazing has started (SAMPLE1) and than 1 hour later (SAMPLE2). The samples were dried at 55ºC for 72 hours until constant weight and than grounded to pass a 1mm screen in a Wiley mill before analysis using the near infra-red spectroscopy (NIR / MPA-"Multi-Purpose Analyzer," Bruker Optics GmbH, Ettlingen, Germany).

6.2.3 Statistical analysis

Descriptive statistics were calculated using Microsoft® Excel® for Windows and all other statistical analyses were conducted using in SAS 9.3. The first 5 days of each period were considered as an adaptation period to observers and experimental routine (AM or PM feed supplementation), followed by 2 periods of 35 days each for data collection. The frequency of behaviours was summarized over the days per period yielding one value for each animal per period. The Shapiro test was used on the model residual information as well as the examination of the normal plot to evaluate the dataset for normal distribution.

The effect of treatment and social rank on the frequency of eating supplement, grazing on paddock, grazing near fence and along the paddock was analysed using mixed procedures (Proc Mixed of SAS). Treatment and social rank were included in the model as fixed effect and period as random effects. The effect of treatment and social rank on the frequency of other behaviours was analysed using generalized linear mixed models (Proc Glimmix of SAS). Treatment and social rank were included in the model as fixed effect, period as random effects and gamma as the type of distribution. Interactions between treatment and social rank were removed from all models as they were not significant ($P > 0.05$). Results of eating supplement, grazing along the paddock and grazing near fence behaviours are reported as least square means ± standard error (S.E.); results of other behaviours are reported as least square means (95% confidence interval).

The relation of treatment, order (the first 3 (FIRST3) or the last 3 (LAST3) heifers that left the place of supplement supply and started grazing), sample (SAMPLE1: immediately after grazing has started and SAMPLE2: 1 hour after the first sample), social rank (dominant, intermediate, subordinate) and crude protein, acid detergent fibre and neutral detergent fibre were analysed using mixed procedure (Proc Mixed of SAS). Treatment, sample, order and social rank were included in the model as fixed effects and period as random effect. Interactions were included in the models when they were significant ($P < 0.05$). Results are reported as least square means ± standard error (S.E.).

6.3 Results

Treatment did not affect the time spent eating supplement or the time spent grazing near the fence (feeding area), but it did affect the total time dedicated to grazing along the paddock ($p<0.0001$) and other behaviours ($p<0.0001$) as shown in Table 3. Heifers spent more time grazing on the AM treatment and performed other behaviours more in the PM treatment.

Despite treatment, the social hierarchy of the group did influence the feeding behaviour of the group. Dominant animals spent more time eating supplement than subordinate ones ($p=0.0008$), which in turn spent more time grazing along the paddock ($p=0.0067$) but not along the fence ($p=0.0008$).

Table 7. Effect of treatment (AM, PM) and social rank (dominant, intermediate or subordinate) on eating supplement (%), grazing (%) and other behaviours (%). (Normal data: least square mean ± standard error; non-normal data: least square mean (95% confidence interval).

Behaviour	Treatment			Social hierarchy			
	AM	PM	p-value	Dominant	Intermediate	Subordinate	p-value
Eating supplement	28.6 ± 0.96	30.8 ± 0.96	0.1113	32.9 ± 1.12[a]	30.2 ± 1.12[a]	26.0 ± 1.32[b]	0.0008
Grazing on paddock	47. ± 7.15[a]	26.1 ± 7.15[b]	<0.0001	30.8 ± 7.27[a]	33.6 ± 7.27[a]	45.2 ± 7.45[b]	0.0020
Grazing near fence	16.1 ± 1.94	19.0 ± 1.94	0.2867	23.8 ± 2.26[a]	18.9 ± 2.26[a]	9.9 ± 2.66[b]	0.0008
Other	2.1 (1.243-2.984)[a]	2.9 (2.071-3.812)[b]	<0.0001	2.4 (1.476-3.230)	2.6 (1.704-3.457)	2.6 (1.764-3.535)	0.1319

The first 3 heifers that left the place of supplement supply and started grazing were 10% dominant, 36.7% intermediate and 53.3% subordinate. The last 3 heifers that left the feeding area and started grazing were 48.3% dominant, 37.9% intermediate and 13.8% subordinate.

The sample was not related to crude protein content, however, there was an effect of treatment (AM: 11.27 ± 1.5 vs. PM: 8.27 ± 1.47; $P < 0.0001$) and an interaction between order and social rank and crude protein content ($P = 0.04$) (Table 4). The LAST3 chose pasture with higher content of FDN (FIRST3: 70.26 % ± 1,52; $P > 0.05$; LAST3: 73.74 % ± 1.53; P = 0.0367). Treatment, sample, order and social rank were not related to FDA (39.28% ± 0.96; P > 0.05).

Table 8. Crude protein (%CP) content of handplucking pasture samples, according to social hierarchy (dominant, intermediate, subordinate) and the order to leave the feeding area and start grazing (First3; Last3).

Content/order	First 3			Last 3		
Crude protein (%CP)	D	I	S	D	I	S
	12.3 ± 1.88 a	8.5 ± 1.55 b	10.2 ± 1.5 a	9.2 ± 1.65	9.3 ± 1.54	8.9 ± 1.78

6.4 Discussion

In our study treatment affected grazing and other behaviours. The heifers spent more time grazing along the paddock when the supplement was delivered in the morning and they showed other behaviours more often when supplement was offered in the afternoon. These findings are not consistent with Adams (1985) who found that beef cattle grazed for a longer period when corn supplement was offered in the afternoon. Scaglia *et al*. (2009) also found that steers receiving supplement in the morning (7am) consumed less forage than those in the other treatments (12am and 4pm), with the highest dry matter intake when supplement was offered at noon compared to 7am and 4pm. For Barton *et al*. (1992) offer supplement for cannulated steers at 6am or 12am did not affect their behaviour but the feed

supplementation reduced grazing time in 1.5 hour. On the other hand, Sheahan *et al*. (2013) concluded that supplementing cows in the morning or in the afternoon does not affect the time spent on grazing or dry matter intake.

All these studies above were conducted in extensive grazing systems but it is important to consider that in our study the heifers were raised under Voisin's rational grazing system and managed to enter into a new paddock every morning with fresh pasture available. According to Gregorini (2012), the major grazing events occur in the early morning and late afternoon/early evening; the later grazing event is the longest and most significant in terms of herbage intake. He also states that the dusk grazing event seems to be an adaptative feeding strategy to maximise daily energy acquisition, providing a steady release of nutrients over night. Grazing behaviour and intake interact strongly with the feed supply–demand balance, pasture composition, and grazing method and the challenge is to present feed to animals at pasture in ways that allow them to meet their dietary preferences, while also allowing high rates of animal production per hectare (CHAPMAN *et al*., 2007). The grazing time is affected by the grazing system, with lower grazing times on rotational systems compared to continuous which may be due to the fact that the cows can anticipate the timing of the daily movement of the electric fence and reduce their time spent grazing residual herbage (PULIDO & LEAVER, 2003).

In our study, the dominant heifers spent more time eating supplement and grazing along the fence than the subordinate ones, which in turn spent more time grazing along the paddock (APPENDIX 1.2). Dominant animals are known to have priority of access to feed resources (TAKANISHI *et al*., 2015) and for grazing ruminants it is related to the priority of access to high-quality grazing areas (BARROSO *et al*., 2000). When the dominant heifers entered the new paddock, they went directly to the feeding area (along the fence) and stayed there for a long time, even after all the grain had been consumed. It may be a strategy to avoid the subordinate heifers from eating supplement as they knew the grain was offered only once a day.

Meanwhile the dominant heifers were eating supplement, the subordinate ones were exploring the paddock and grazing in preferred patches. In heterogeneous flocks, dominant sheep use more intensively the most preferred areas and low-ranked use less preferred areas; but when high-ranked individuals were removed from the flock, low-

ranked sheep shift their selection patterns by increasing the use of the most preferred areas and strongly avoided to use less preferred sites (DiVIRGILIO & MORALES, 2016). Manson and Appleby (1990) found that cows of similar rank were feeding together compared with of dissimilar rank and that the largest nearest-neighbour distance was found between animals of low and high rank.

Throughout the experiment we have noticed that the subordinate heifers changed their behaviour and when entering the new paddock they were no longer involved in the dispute of the supplement but going straight to graze along the paddock. The desire to ingest food or to avoid clashes with other animals is variable and influences the animal's decision-making. The priority that an animal gives to a given resource is dependent on its motivation to obtain it (LINDBERG, 2001). For Val-Laillet *et al*. (2008), individuals have different motivations according to the resource and they found that competition in the feeder was responsible for 88% of the observed displacements, indicating that the access to food is a priority for cattle.

The pasture ingested by the first 3 animals that left the feeding area to graze along the paddock was related to their social hierarchy. The subordinate heifers were among the first to graze along the paddock and were able to ingest forage with the same crude protein content as the dominant ones, while the intermediate ones were left with the pasture of inferior quality, as shown in Table 8. In dairy cattle, the first animals moving to an allocation of fresh pasture after a milking session are offered feed of greater nutritive value compared with those arriving last and it is closely related to social hierarchy as they show a consistent milking order (SCOTT *et al*., 2014). In pasture-based systems, the amount of pasture consumed and its nutritive value may influence the between-cow variability in response to supplement and will need to be considered as part of a dynamic model for calculating optimum supplementation rates (HILLS *et al*., 2015).

As highly dominant animals may obtain priority on resources access in intensive production conditions (MIRANDA-DE-LA-LAMA *et al*., 2011) and the information on the access to food can be relatively easy to be collected by farmers, the feeding order can be used as an on-site simple attribute of social dominance in intensive beef cattle production systems (TAKANISHI *et al*., 2015). Under pastoral systems, synergies between animals' and farmers' grazing decisions have the

potential to offer more greater benefits to our livestock, our landscape and ourselves (GREGORINI *et al*., 2017).

6.5 Conclusions

In Voisin's rational grazing system it is better to offer feed supplement (such as grain) when the animals get into a new paddock. Subordinate heifers can choose to graze best quality patches while the dominant heifers deal to eat grain supplement instead of graze along the paddock and prevent the other animals of selecting the best feeding sites.

6.6 References - at the end of document.

7. General discussion

In this thesis the social dominance was studied regarding to its relation to the feeding behaviour of cattle. In the systematic review it was clear that, as we already empirically assumed, the social hierarchy affects the way cattle access the feeding resources. Despite there was a great variability among the selected studies on the systematic review, specially related to their experimental design (regrouping, altering stocking density, modifying diets and feeding areas), all of them came to the same conclusion as our field researches: high ranking animals spend more time on the feeder or feeding areas than the low ranking animals. One relevant matter is that only two of the 418 studies screened for the systematic review according to all pre-defined criteria, were performed with cattle raised under grazing systems being that only one on rotational grazing system (Voisin's grazing system). Almost all research efforts are towards housed cattle but It is important to consider that supplemental programmes are also used for grazing animals and that the social hierarchy will be established independent of the rearing conditions.

Even that we are aware that dominance is not consistent across different resources, the motivation for food is an important issue to be addressed. The motivation can lead the animals to behavioural changes as shifting their feeding time (to feed in less preferred hours), move away from the herd (to graze away from dominant animals) and even perform affiliative behaviours (from subordinates towards dominants). All the changes may be (or not) endorsed by the farmers according to what they plan for the herd management and according to the infrastructure of the farms.

The existence of a social hierarchy in a given group is something positive specially in terms of group organization, protection and reproduction. But eventually, mainly as a result of inadequate management, the negative effects can stand out the positive ones and be harmful specially for the subordinate animals. Based on this we than designed two original research experiments to test subtle changes in management with the purpose of mitigate the negative effects of social hierarchy over low ranking animals.

In the first one, two different ways to offer grain supplement were tested (continuous line x individual piles) and in the second one, two different times to offer grain supplement were tested (beginning of

paddock use and half time of paddock occupation considering Voisin Rational Grazing System). Despite the particularities of both studies, results were pretty much the same, i.e., dominant heifers spent more time eating grain supplement while the subordinate ones spent more time grazing.

We hypothesized that while the high ranking heifers were busy eating supplement the low rank ones would be free to either compete for grain or to choose the best grazing sites. Our results confirmed that hypothesis and we could clearly see this happening as the subordinate would enter in the new paddock and start grazing immediately instead of competing for grain (the pictures in the Appendix 1 are illustrative of that moment). Even when the supplement offer is limited, as it happens during the winter time in the subtempered climate regions of the southern hemisphere, the subordinate animals get benefit from the supplement offer when it happens at the time the herd gets into a new paddock on rotative grazing systems.

With all that we affirm that social dominance is definitively an important behaviour to consider when planning or managing cattle herds. As the establishment of a hierarchy is inherent to groups of social animals as cattle, and even when we regroup them it will be established again, the farmers who offer feed supplement to their animals must be aware of it. They can redesign systems or plan the management according to that and mitigate these effects by altering feeding area design (like more feeders or barriers), providing more space per animal on feeders, decreasing the group size, offering food more frequently and/or for longer periods. As our role as researchers, we shall not only to produce scientific knowledge but also to bring it closer to reality by promoting the empowerment of farmers to make conscious decisions.

8. General conclusion

An overall conclusion is that social dominance affects cattle feeding behaviour and must be taken into account when planning or managing herds of cattle. Even though in some cases the subordinate animals may adopt different strategies to cope with challenging situations and alter their feeding behaviour, the farmers may not easily perceive the negative impacts of social struggling. Supplemental feed programs, even when offered on pasture, must be planned to mitigate the negative effects of social hierarchy.

According to our results, we confirm the hypothesis that grazing cattle under rotative management systems, who frequently move into a new paddock (as in Voisin's Rational Grazing System) should receive feed supplement on paddock entry time and not after hours of paddock occupation, regardless the way it is offered, if in continuous line or individual piles. We realized that in this way, the subordinate animals get the opportunity to select the best grazing patches while the dominant ones consume the feed supplement (such as grain).

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Appendix

1. Illustrative photos of studies 2 and 3

Appendix 1.1: Study 2 - subordinate animals graze while the others eat grain supplement on continuous fenceline feeding.

Appendix 1.2: Study 3 - group of Braford heifers receiving supplement; three subordinate animals grazing while the others eat grain supplement.