UNIVERSIDADE ESTADUAL PAULISTA “JÚLIO DE MESQUITA FILHO”
FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS
CÂMPUS DE JABOTICABAL

IMPLICAÇÕES DA DISPONIBILIDADE DE ESPAÇO NO CONFINAMENTO DE BOVINOS DE CORTE

Fernanda Macitelli Benez
Zootecnista

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Orientador: Prof. Dr. Mateus J. R. Paranhos da Costa

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DADOS CURRICULARES DO AUTOR

FERNANDA MACITELLI BENEZ - Nascida na cidade de São Paulo – SP, no dia 11 de agosto de 1977. Filha de Bruno Antônio Macitelli e Maria Aparecida Pacheco Macitelli. Zootecnista, graduada pela FCAV – Unesp em 1999 e Mestre em Zootecnia pela mesma Universidade, em 2003. Trabalhou durante oito anos como Zootecnista e administradora de fazendas do Grupo RPA no Mato Grosso. Professora de bovinocultura durante três anos (2005 a 2008) na Universidade de Cuiabá, no município de Rondonópolis e professora temporária da Universidade Federal de Mato Grosso de 2005 a 2007. Atualmente é pecuarista e professora efetiva da disciplina de Bovinocultura de Corte e Comportamento e Bem-estar animal na Universidade Federal de Mato Grosso, campus de Rondonópolis.

"O animal é tão ou mais sábio do que o homem: conhece a medida da sua necessidade, enquanto o homem a ignora."

(Demócrito)

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SUMÁRIO

LISTA DE ABREVIATURAS

mm – milímetro (millimeter)
cm – centímetro (centimeter)
m – metro (meter)
m² - metro quadrado (square meter)
h – hora (hour)
min – minuto (minut)
kg – quilograma (kilogram)
°C – graus Celsius (Celsius degree)
AT – temperature ambiente (environmental temperature)
RH – umidade relativa do ar (relative humidity)
BGT – temperatura do globo negro (black globe temperature)
LD – dificuldade de locomoção (locomotion deficits)
HA – alteração de casco (hoof alterations)
TE – alteração de tegumento (tegument alteration)
DI – diarreia (diarrhea)
BD – dificuldade de respirar (breathing difficulty)
MA – área medular da glândula adrenal (adrenal gland medullar area)
CA – área cortical da glândula adrenal (adrenal gland cortical area)
ACTH – hormônio adenocorticotrófico (adenocorticotropic hormone)
BRD – doença respiratória bovina (bovine respiratory disease)
TDN – nutrientes digestíveis totais (total digestible nutrients)
OR – razão entre possibilidades (odds ratio)
RC – classe de referência (reference class)
Ibw – peso vivo inicial (inicial body weight)
Mbw – peso vivo intermediário (intermediate body weight)
Fbw – peso vivo final (final body weight)
Dgw1 – ganho de peso médio diário no período 1 (first period daily weight gain)
Dgw2 - ganho de peso médio diário no período 2 (second period daily weight gain)
Dgwt – ganho de peso médio diário no período total (total period daily weight gain)
Cw – peso da carcaça (carcass weight)
Aw – peso da glândula adrenal (adrenal gland weight)
Raw – peso da glândula adrenal direita (right side adrenal gland weight)
Law – peso da glândula adrenal esquerda (left side adrenal gland weight)
N – número (number)
SIF – Serviço de Inspeção Federal (Federal Inspection Service)
DIPOA - Departamento de Inspeção de Produtos de Origem Animal (Department of Animal Products Inspection)
MAPA – Ministério da Agricultura, Pecuária e Abastecimento (Ministry of Agriculture, Livestock and Food Supply)

IMPLICAÇÕES DA DISPONIBILIDADE DE ESPAÇO NO CONFINAMENTO DE BOVINOS DE CORTE

RESUMO - O objetivo dessa pesquisa foi avaliar as implicações da disponibilidade de espaço no bem-estar, desempenho e qualidade de carcaça e carne de bovinos de corte confinados. Foram confinados 1350 machos inteiros em três disponibilidades de espaço: 6 (T6), 12 (T12) e 24 (T24) m^2/animal. Todos os animais receberam a mesma dieta. Foram utilizados indicadores de bem-estar animal com base no ambiente (escore de poeira e profundidade da lama) e com base nos animais, sendo parte destas medidas realizada com os animais alojados nos currais do confinamento, como as medidas de indicadores comportamentais (número de animais em pé, deitado, ou no cocho), de conforto (grau de sujidade dos animais), e de saúde (número de tosses e espirros por minuto, porcentagens de animais com diarreia, alteração de cascos, problemas de locomoção, alteração de tegumento, e com corrimentos nasal e ocular), e parte após o abate dos animais, no frigorífico, avaliando-se indicadores de saúde, com o diagnóstico macroscópico de vísceras (porcentagem de animais com bronquite, enfisema pulmonar, nefrite e cisto urinário), e indicadores de estresse, com a coleta das glândulas adrenais direita e esquerda de 20% dos animais de cada tratamento (medindo o peso e as áreas cortical e medular). Foram avaliados também indicadores de desempenho (peso final, ganho de peso médio diário, peso da carcaça quente) e de qualidade das carcaças (número e severidade dos hematomas e grau de acabamento de gordura) e da carne (pH). Em geral, os resultados mostraram que o T24 ofereceu melhores condições ambientais para realizar a fase de terminação dos bovinos que os demais tratamentos, evidenciada pela menor frequência de ocorrência de poeira e profundidade da lama ($P < 0,01$), menores porcentagens de animais com corrimentos nasal e ocular e com problemas de locomoção ($P < 0,05$), além de menor porcentagem de animais com diagnóstico de bronquite, enfisema pulmonar, nefrite e cisto urinário. Além disso, T24 apresentou maior ganho de peso médio diário ($P < 0,01$), menor número médio de hematomas novos e superficiais por carcaça, e também menores médias de peso e da área cortical da glândula adrenal ($P < 0,01$). Apesar de T6 ter apresentado maior resultado de pH da carne ($P < 0,05$), e haver diferença significativa na frequência de distribuição dos escores de acabamento de gordura ($P < 0,05$), todos os tratamentos apresentaram médias de pH e acabamento de gordura dentro do que é esperado para assegurar uma boa qualidade da carne. Conclui-se que aumentar a disponibilidade de espaço para bovinos de corte em confinamento reduz o estresse, favorece o bem-estar animal e melhora o desempenho e a qualidade das carcaças dos animais.

Palavras chave: ambiente, bem-estar animal, comportamento, desempenho, saúde

IMPLICATIONS OF THE SPACE AVAILABILITY IN THE BEEF CATTLE FEEDLOTS

SUMMARY - The objective of this research was to evaluate the implications of the space availability in feedlot beef cattle on animal welfare, performance and carcass and meat quality. One thousand, three hundred and fifty bulls were confined within three space allowance: 6 (T6), 12 (T12) and 24 (T24) m^2/animal. All animals received the same diet. The animal welfare were assessed using environmental (dust score and mud depth) and animal based indicators, part of these measurements was carried out with the animals housed in confinement pens by using behavioral (number of animals standing, lying down, or in the feed bunk), comfort (percentage of dirty animals), and health indicators (number of coughs and sneezes per minute, and the percentages of animals with diarrhea, hooves alterations, locomotion problems, tegument alterations, and nasal and ocular discharges), and part after slaughtering the animals, evaluating health indicators, with macroscopic diagnosis of animal viscera (percentage of animals with bronchitis, emphysema, nephritis and urinary cyst), and stress indicators besides the collection of the left and right adrenal glands from 20% of the animals from each treatment (to assess the weight and cortical and medullar areas). Growth performance (final body weight, average daily gain weight, hot carcass weight), and carcasses (number and severity of bruises and degree of fat finishing), and meat quality (pH) indicators were also measured. In general, the results showed that the T24 offered better environmental conditions for the finishing phase of beef cattle than the other treatments, evidenced by the lower frequency of occurrence of dust and mud depth ($P < 0.01$), lower percentages of animals with nasal and ocular discharges and locomotion problems ($P < 0.05$), and lower percentage of animals diagnosed with bronchitis, emphysema, nephritis and urinary cyst. In addition, T24 showed higher mean of daily weight gain ($P < 0.01$), lower means in the number of new and superficial bruises per carcass, and also lower means of adrenal gland weight and cortical area ($P < 0.01$). Although, the significant difference for the distribution of the fat covering score, and T6 have shown highest mean for meat pH ($P < 0.05$), all treatments displayed means within the range that is expected to ensure the meat quality. It is concluded that increasing the availability of space in beef cattle feedlots reduces stress, promotes animal welfare and improves performance and the quality of the carcasses of animals.

Keywords: animal welfare, behavior, environment, health, performance

CAPÍTULO 1. Considerações gerais

1. Introdução

A bovinocultura de corte brasileira apresentou transformações notáveis nas últimas décadas, resultantes principalmente da estabilidade econômica, da utilização de cruzamentos inter-raciais visando precocidade e melhoria na qualidade da carne, bem como da aplicação de sistemas mais intensivos de produção como integração lavoura-pecuária, silvipastoris, semi-confinamento e confinamento (Vilella et al., 2008; Lemaire et al., 2014; Oliveira e Millen, 2014, Gil et al., 2015).

De maneira geral, a aplicação desses sistemas vai além da ideia remota de favorecer a produção de bovinos em períodos de menor disponibilidade de forragens, o que coincide com a época de melhores preços da arroba. Atualmente os sistemas intensivos de produção caracterizam-se como adjuvantes da agricultura, uma vez que aumentam a disponibilidade de áreas para a produção de grãos e de outro produtos agrícola, otimizam o uso de maquinários e mão de obra, além de promoverem maior aproveitamento dos resíduos da produção de importantes culturas do panorama agrícola brasileiro. Adicionalmente, Oliveira e Millen (2014) afirmaram que a crescente intensificação do sistema de produção brasileira de bovinos de corte também é resposta à demanda do mercado por carne de qualidade.

Dados do Ministério da Agricultura Pecuária e Abastecimento (MAPA, 2014) indicam que houve acréscimo na produtividade da bovinocultura de corte brasileira na última década, uma vez que a estimativa de crescimento do rebanho foi de apenas 4% (de 204 milhões de animais em 2004 para 212 milhões em 2013), enquanto o número de animais abatidos aumentou em 30% (de 20,4 milhões de animais em 2004 para 26,7 milhões em 2013). Um dos fatores responsáveis pelo aumento de produtividade brasileira é a crescente utilização do confinamento para bovinos na fase final de produção, como caracterizado pelos dados da Associação Nacional dos Confinadores (Assocon, 2014), que mostraram que o número de animais confinados dobrou entre os anos de 2010 (2 milhões de bovinos) e 2013 (4 milhões de bovinos), e com estimativa de que 4,4 milhões de bovinos tenham sido confinados em 2014. Existem ainda projeções de que, no Brasil, até o ano de 2023 sejam produzidas 2,4 milhões de toneladas de carne oriundas de confinamento, ou seja, praticamente o triplo que em 2013 (Rabobank, 2014).

Diante desse contexto, visando aprimorar as práticas utilizadas em confinamento, técnicos e pecuaristas investem no uso de tecnologias, caracterizadas pela automação na preparação e distribuição dos alimentos, avanços no manejo nutricional (com atenção especial à formulação das dietas) e utilização de animais com maior potencial produtivo. Entretanto, é necessário ressaltar que apesar do confinamento de bovinos ser benéfico para a melhoria na eficiência de produção de carne, existe o risco deste sistema de criação não contemplar aspectos importantes relacionados às necessidades dos animais, dentre eles, boas condições de conforto físico e psíquico (Boissy et al., 2007; Estevez et al., 2007; Fraser et al., 2013).

Apesar do confinamento no Brasil ocorrer apenas na fase de terminação e por um período curto de tempo, em média 80 a 100 dias (Duarte, 2014; Mello e Cassol, 2014), as diversas mudanças nas condições de criação que são impostas aos animais tem importantes impacto no seu bem-estar. As alterações mais comuns se caracterizam pela dependência direta do homem para o atendimento de recursos essenciais (como oferta de alimento e água, por exemplo), substituição de dieta rica em fibra por outra mais concentrada, e oferecimento de água em pequenos reservatórios. Adicionalmente, pode existir ainda a mistura de animais de diferentes rebanhos no mesmo lote, ausência de sombra e substituição de amplo espaço por área restrita, aliada a alta densidade de animais.

Além dos elementos citados, a baixa disponibilidade de espaço potencializa outros fatores que afetam o bem-estar dos animais, dificultando a adaptação e reduzindo o desempenho dos mesmos, como a presença constante de poeira e/ou lama no ambiente (West, 2011; Mader, 2011). Como agravante, agentes químicos e biológicos presentes na poeira e lama, associados à redução da imunidade decorrente do estresse causado pelo confinamento (Fell et al., 1999), são os principais responsáveis pelas ocorrências de doenças respiratórias (Edwards, 2010), que causam

70 a 80% dos casos de morbidade e 40 a 50% dos casos de mortalidade nos bovinos confinados (Smith, 1998).

Fraser et al. (2013) afirmaram que o bem-estar ruim não é só uma consequência de doenças, mas também de outras reações dos animais frente a um ambiente desafiador. Segundo Welfare Quality® (2009), a saúde é apenas um dos aspectos que pode ser utilizado como indicador de bem-estar animal, sendo necessário avaliar outros indicadores, como por exemplo, os relacionados à alimentação, alojamento e comportamento, para que assim se tenha uma avaliação mais segura do estado de bem-estar de um dado animal.

É importante destacar que todos os envolvidos na cadeia produtiva da carne bovina devem estar conscientes de que, na percepção da sociedade, o bem-estar de bovinos confinados é reduzido quando comparados ao de bovinos mantidos em pastagens (Lee et al., 2013). Isto ocorre, provavelmente, pela perspectiva de que a restrição de espaço, por si, é uma situação estressante e que causa sofrimento aos animais (Del Campo et al., 2014; Spooner et al., 2014), além de ser uma questão ética importante na produção dos mesmos.

Nesse contexto, são necessários estudos que relacionem alterações ambientais e de manejo impostas aos animais confinados, e seus potenciais efeitos negativos no bem-estar animal e, consequentemente, na eficiência de produção de carne de qualidade.

Diante do exposto, o objetivo do presente estudo foi avaliar a implicação da disponibilidade de espaço em confinamento no bem-estar, desempenho e qualidade da carcaça e carne de bovinos de corte.

2. Revisão de literatura

Após a segunda guerra mundial, a crescente demanda por proteína de origem animal e, posteriormente, devido à pressão de outros fatores econômicos, levaram as cadeias produtivas de carnes a investirem em estruturas nas quais pudessem aumentar a produção em espaços cada vez menores (Vanhonacker et al., 2009; Fraser et al.; 2013). No entanto, as necessidades dos animais não foram levadas em consideração nesses sistemas intensivos de produção (Fraser, 1983).

Muitos são os fatores que podem afetar o desempenho dos animais nos variados sistemas de criação, sendo o ambiente um aspecto extremamente relevante. Logo, é importante apresentar o conceito de ambiência, como sendo “o espaço constituído por um meio físico e, ao mesmo tempo por um meio psicológico, preparado para o exercício das atividades do animal que nele vive” (Paranhos da Costa, 2000). Assim, o ambiente dos bovinos mantidos em regime de confinamento envolve todos os elementos capazes de afetar a vida dos mesmos, de forma positiva ou negativa, sendo, de acordo com Averós et al. (2014), a disponibilidade de espaço o elemento primordial, visto que sua limitação impacta severamente o bem-estar dos animais e consequentemente a produção. A indicação de disponibilidade de espaço para a criação de animais é um tema complexo, uma vez que esta pode variar com o tamanho do grupo e como os membros do grupo dividem esse espaço ao longo do tempo (Petherick, 2007).

Na literatura científica brasileira são escassas as recomendações de disponibilidade de espaço para bovinos confinados, e na internacional são conflitantes, uma vez que existem estudos que utilizaram desde 1,2 (Gupta et al., 2007) até 33 m^2/animal (Mader, 2011). Isso ocorre devido às particularidades de cada país ou região onde os bovinos são confinados, que apresentam diferentes instalações e tempo de permanência no confinamento em função do clima, raças e idade dos animais. No Brasil, disponibiliza-se em média 12 m^2/animal, mas não existe um consenso, sendo recomendado por técnicos de 8 a 50 m^2/animal (Souza et al., 2003; Quadros, s.d.).

É inegável que a adoção de sistemas intensivos pode aumentar a capacidade de produção de bovinos (Assocon, 2014), e que a demanda pela mesma continuará crescente nas próximas décadas (Rabobank, 2014). Entretanto, ressalta-se que muitas análises financeiras são realizadas visando à lucratividade dos sistemas, mas nenhuma delas considera o quanto se deixa de ganhar ao manter os animais tentando se adaptar a um ambiente que não atende às suas necessidades físicas e psíquicas.

A tentativa do organismo animal em adaptar-se a ambientes desafiadores provoca um conjunto de alterações fisiológicas e comportamentais, que caracterizam o estado de estresse (Selye, 1936), com potenciais efeitos negativos no bem-estar animal e na produção (Bearden e Fuguay, 1980). Em situações estressantes há ativação do eixo hipotálamo-hipófise-adrenal (HHA), com a liberação do hormônio liberador de corticotrofina (CRH), produzido pelo hipotálamo, que atua na hipófise estimulando a produção do hormônio adrenocorticotrófico (ACTH), que atua no córtex das glândulas adrenais, estimulando a secreção de glicocorticoides (Möstl e Palme, 2002; Franci, 2005). Os glicocorticoides, principalmente o cortisol no caso dos bovinos, são responsáveis por controlar a resposta inflamatória deflagrada durante o estresse agudo, como também mobilizar energia principalmente para o cérebro, coração, fígado e rins, via aumento da neoglicogênese, glicólise, inibição da captação de glicose, e ativação da proteólise e da lipólise (Habib et al., 2001; Carroll e Forsberg, 2007). Nos casos de estresse crônico, em que os níveis de glicocorticoides circulantes são constantemente elevados, pode ocorrer catabolismo proteico, hiperglicemia, atrofia do tecido linfoide, redução do número de linfócitos e anticorpos, ocasionando falhas no sistema imunológico e reprodutivo, lesões aos tecidos e órgãos, inibição de crescimento e consequentemente redução na produção, e até mesmo alterações psicológicas, como depressão (Matteri et al., 2000; Tsigos e Chrousos, 2002; Carroll e Forsberg, 2007).

Sintetizando, bem-estar animal e estresse são conceitos associados, mas devem ser considerados como vertentes opostas de um processo comum, pois a boa condição de bem-estar animal não pode ser alcançada quando o animal está estressado (Veissier e Boissy, 2007).

O tema bem-estar animal tem sido pauta de grandes discussões, entre os diferentes elos da cadeia produtiva da carne, principalmente quando o foco está na criação intensiva de animais de produção (OIE, 2002). Entretanto, o valor atribuído ao bem-estar dos animais difere entre os elos, onde os produtores e a indústria atribuem ao bem-estar animal um valor econômico já que existem efeitos diretos na produção e na qualidade do produto final (Del Campo et al., 2014); enquanto que a sociedade, em geral, vinculam o bem-estar dos animais com saúde ou sofrimento (Vanhonacker et al., 2009; Spooner et al., 2014). Porém, a definição de bem-estar animal é complexa, podendo ser feita com base nos estados emocionais, ou seja, pelos sentimentos experimentados pelos animais (Dawkins, 1990 e Duncan, 1993) ou por meio do funcionamento biológico dos animais, definindo bem-estar como o estado do organismo em suas tentativas de se ajustar ao seu ambiente (Broom,1986).

Por ser uma questão que envolve importantes dimensões políticas, econômicas, científicas e éticas, faz-se necessário a adoção de uma definição mais ampla e detalhada, onde: “bem-estar animal significa como um animal está respondendo às condições em que vive. Um animal é considerado em bom estado de bem-estar se (com comprovação científica) estiver saudável, confortável, bem nutrido, seguro, capaz de expressar seu comportamento natural, e se não estiver sofrendo com dores, medo e angústias. Bem-estar animal requer prevenção contra doenças e tratamento veterinário, abrigo adequado, gerenciamento, nutrição, manejo cuidadoso e abate humanitário” (OIE, 2002).

Por fim, para que o bem-estar possa ser comparado em situações diversas ou avaliado em uma situação específica, deve-se empregar avaliações científicas livres de visões antropocêntricas em relações aos animais. Uma vez terminada a avaliação, esta deve ser capaz de prover informações necessárias para que decisões éticas possam ser tomadas em relação à produção dos animais. Os melhores indicadores de bem-estar animal são os que se referem às características do animal indivíduo e não a algo proporcionado pelo homem (Broom e Molento, 2004), como o comportamento, a saúde, o desempenho e as alterações fisiológicas.

O comportamento dos animais é uma ferramenta reconhecida para a avaliação do seu bem-estar (Welfare Quality®, 2009). Segundo Fraser (1983) é seguro utilizar os comportamentos de manutenção para determinar se animais mantidos em confinamento estão em um ambiente que os permita expressar seus comportamentos naturais, uma vez que pode ocorrer redução ou impossibilidade dos animais apresentarem comportamentos exploratórios (em relação ao ambiente ou a novos estímulos), seleção de alimentos (principalmente quando a dieta é composta por grãos), deslocamentos e deambulação (perambulação, andamentos naturais como trote e galope, usa de rotas específicas para andar e deitar, etc.) e manutenção corporal (termorregulação e limpeza, por exemplo).

De acordo com Brörkens et al. (2009), o comportamento de deitar-se dos bovinos é associado ao descanso, e a restrição de espaço pode privar ou dificultar esse comportamento, aumentando o risco de lesões nas articulações e de claudicação. Estudo realizado utilizando diferentes disponibilidades de espaço para vacas leiteiras confinadas (7,26 e 9,18 m²/animal) mostrou que houve redução do tempo que as vacas permaneciam deitadas quando a disponibilidade de espaço foi menor (Lobeck-Luchterhand et al., 2015). Resultados semelhantes foram apresentados por Gygax et al. (2007), onde ao confinar bovinos com disponibilidade de espaço de 2,5; 3,0; 3,5 e 4,0 m²/animal concluíram que, conforme há restrição de espaço, se reduz linearmente o tempo que os animais ficam deitados, além dos mesmos não estenderem as pernas como deveriam para deitar, e ainda alteraram as posições corporais enquanto deitados com menor frequência.

Os comportamentos relacionados ao descanso e alimentação de vacas leiteiras confinadas com diferentes disponibilidades de espaço, são bem documentados, apesar de contraditórios. Estudos realizados por Hill et al. (2009) e Krawcsel et al. (2012) mostraram que apenas o tempo de descanso, e não o de alimentação e ruminação, foi relacionado com a disponibilidade de espaço, diferente de Friend et al. (1979) e Huzzey et al. (2006) que encontraram associações entre todas essas variáveis. Bristow e Holmes (2006) e Zoccola et al. (2012) afirmaram que a redução do tempo de ruminação está intimamente relacionada com o aumento de cortisol circulante em condições de estresse crônico. Nesse contexto, Krawcsel et al. (2012) justificaram que a diferença entre os resultados sugere que mudanças físicas no ambiente de um animal requer um tempo longo antes que alterações nos comportamentos e na produção sejam evidentes. Vale ressaltar que nos estudos apresentados acima há dois fatores que se confundem, uma vez que os autores estudaram a disponibilidade de espaço da baia juntamente com a do cocho. Mas esse fato não invalida os resultados, que de maneira geral indicam que o espaço é importante, independente de qual recurso esteja disponibilizado no mesmo.

A restrição de espaço no confinamento de bovinos também está relacionada ao aumento de ocorrências de comportamentos sociais agonísticos, resultantes de maior probabilidade de haver encontros competitivos e violação do espaço individual (Fraser, 1980; Lindberg, 2001; Rodenburg e Koene, 2006). Resultados encontrados por Kondo et al. (1989) evidenciaram que a manutenção de um espaço individual por cada animal parece ser uma necessidade especial, uma vez que existe correlação negativa entre comportamentos agonísticos e espaço disponível para bovinos confinados ($r^2 = -0,48$; $P < 0,01$), e ainda comprovaram, igualmente a Gygax et al. (2007), que esses animais optam em manter maior distância entre eles quando existe espaço para tal.

Outro comportamento social relevante para a avaliação do bem-estar de bovinos confinados é o de monta, responsável pela remoção de 1 a 3% dos animais do confinamento, podendo até ocasionar a morte dos mesmos (Blackshaw et al., 1997). Klemm et al. (1983) destacaram que a monta está vinculada a feromônios, podendo ser definida, primeiramente, como um comportamento sexual, mas também como uma atitude de imposição ou auto-proteção, caracterizando-se como um comportamento agressivo, sendo presente de maneira mais intensa entre os bovinos confinados, principalmente em ambientes onde recursos como sombra, alimento e espaço são disputados. De acordo com Blackshaw et al. (1997), apesar de ser um comportamento natural entre bovinos, o comportamento de monta pode se tornar uma síndrome quando alguns animais são montados constantemente (receptores) por muitos outros (autores), sendo então considerado um comportamento anômalo. Além disso, existem outros tipos de comportamentos anormais, como por exemplo, enrolar de língua ou lamber e morder instalações, que ocorrem principalmente quando os animais são mantidos em condições de restrição de espaço e agravada pela alta densidade animal (Lindberg, 2001; Broom e Fraser, 2007).

De acordo com Bartolomucci (2007), existe uma relação muito forte entre fatores sociais, estresse e saúde, uma vez que, na vida em grupo, existem relações positivas e negativas que afetam psicologicamente e fisicamente os animais. Muitos dos problemas de saúde em bovinos podem ser potencializados pelas alterações ambientais provocadas pela restrição de espaço, como a crescente presença de lama (Mader, 2011) e/ou poeira (West, 2011), além dos agentes tóxicos (May et al., 2012) e patogênicos (Edwards, 2010) presentes nas mesmas. A presença de poeira está relacionada com o tamanho das partículas do solo, condições climáticas, movimentação dos animais e de veículos (West, 2011), e aumenta o risco de doenças, principalmente as respiratórias (Edwards, 2010). Já o acúmulo da lama está associado às falhas no sistema de drenagem das instalações, acompanhado ao acúmulo de dejetos dos animais e maior ocorrência de chuva (Mader, 2011). Scharwtzkopf-Geinswein et al. (2012) alertaram quanto aos possíveis efeitos deletérios causados pela presença constante e abundante de lama, como claudicação, doenças nos cascos, injúrias na pele e dificuldade de caminhar e deitar, que afetam negativamente o desempenho dos bovinos confinados (Mader, 2001; Taylor et al., 2010).

Krawcsel et al. (2012) afirmaram que muitos dos problemas de saúde dos bovinos confinados surgem devido à baixa imunidade em resposta ao estresse exercido pela restrição de espaço. Segundo Franci (2005), desafios físicos e psíquicos, quando crônicos, resultam em um mecanismo de retroalimentação entre o sistema endócrino e imune, onde a hiperativação do eixo HHA secreta glicocorticoides inibitórios do sistema imune, que por sua vez produzem citocinas estimuladoras da produção de CRH pelo hipotálamo, fechando o ciclo. Desta forma, as células responsáveis pela imunidade são capazes de se comunicar com o cérebro por meio do eixo HHA (Bartolomucci, 2007).

A alta concentração de glicocorticoides liberados em situações de estresse crônico são responsáveis por modificações diretas e indiretas em todas as células do corpo (Habib et al., 2001), resultando nas mais diversas alterações fisiológicas que podem ser utilizadas como indicadores para avaliar o bem-estar animal de várias espécies, como: frequência respiratória (Franci, 2005), temperatura, níveis circulantes de glicose, leucócitos (Habib et al., 2001), cortisol e seus metabólitos (Fisher et al., 1997, Möstl e Palm, 2002), alterações funcionais do trato gastrointestinal (Habib et al., 2001; Franci, 2005), cardíaca (Black e Garbutti, 2002), renal (Benchimol et al., 2010; Bruce et al., 2015) e hepática (Rodríguez-Sureda et al. 2007; Duan et al., 2014). Além disso, pode causar também alterações anatômicas, principalmente das glândulas adrenais (Taylor e Constanzo, 1975; Alario et al., 1987; Szigethy et al. 1994; Mounier et al., 2005), e até mesmo psicológicas, resultando em alterações comportamentais importantes (Tsigos e Chrousos, 2002; Franci et al. 2005; Bartolomucci, 2007).

Para avaliar a saúde dos bovinos confinados, foram recomendados pelo Welfare Quality® (2009) alguns indicadores visuais como a frequência de ocorrência de espirros e tosses, a porcentagem de animais com corrimentos nasal e ocular, a dificuldade para caminhar, os problemas nos cascos, sujidade corporal, sinais de timpanismo e diarreia, entre outros. Ademais, Elsasser et al. (2011) sugeriram que a inapetência e menor consumo de alimento, letargia, diminuição da atividade e febre são outros indicadores também associados à saúde dos animais, e que podem ser considerados na avaliação do bem-estar animal.

É importante destacar que antes de realizar as avaliações de bem estar dos animais, deve-se caracterizar a origem, intensidade e duração do agente estressor (Bartolomucci, 2007), assim como considerar que a capacidade de adaptação individual dos animais ao mesmo é dependente também de suas experiências (Mason, 2000), caso contrário, o indicador utilizado pode não ser eficaz. Por exemplo, Friend et al. (1979) associaram o estresse gerado pela restrição de espaço no confinamento de bovinos à maior atividade das glândulas adrenais, mas este resultado não foi confirmado por Fisher et al. (1997), Gupta et al. (2007) e Krawczel et al. (2012), talvez pelo fato das condições e os períodos experimentais terem sido distintos entre o primeiro e os demais estudos.

O conjunto das reações fisiológicas originadas pelo estresse crônico afeta os melhores indicador de sucesso na produção animal: os desempenhos produtivo e reprodutivo. Independente da espécie, os hormônios relacionados à reprodução, lactação, crescimento e consumo, como o folículo estimulante, luteinizante, do crescimento, prolactina, grelina, leptina, insulina, entre outros, apresentam sua produção e/ou funções reduzidas devido às altas concentrações circulantes dos hormônios relacionados ao estresse crônico, como hormônio liberador de corticotrofina, vasopressina, tireotrófico e os glicocorticoides, sendo este último responsável por gerar maior disponibilidade de glicose ao organismo, mas que não é eficientemente utilizada pelos tecidos periféricos devido à sensibilização das células à insulina provocada indiretamente pelos próprios hormônios do estresse (Phillips et al., 1998; McCormick et al., 1998; Habib et al., 2001; Uchoa et al., 2014) . Resumidamente, o animal pode até se alimentar normalmente, mas a eficiência de utilização da energia é reduzida pelo estresse (Manson, 2000; Matteri et al., 2000), assim como a composição do ganho de peso é alterada em função da diferenciação do metabolismo dos nutrientes nos diferentes tecidos (Elsasser et al., 2011).

Segundo Fell (1999) existe correlação negativa entre a concentração de cortisol circulante e o ganho de peso ($r = -0,544$; $P < 0,025$) de bovinos confinados, resultado este corroborado por Gupta et al. (2006), que avaliaram diferentes disponibilidades de espaço no confinamento de bovinos, e observaram melhor ganho de peso e menor concentração de cortisol circulante em animais mantidos a 4,4 m²/animal (1,26 ± 0,22kg/dia) que em 1,2 m²/animal (0,59 ± 0,22kg /dia). Resultados encontrados Fisher et al. (1997) mostraram que as novilhas mantidas em 1,5 m²/animal ganharam menos peso (0,52 kg/dia) que aquelas mantidas a 2,0; 2,5 e 3 m²/animal (0,65; 0,70 e 0,69 kg/dia, respectivamente); no entanto, esses autores não observaram diferenças significativas no comportamento social nem nos valores da concentração de cortisol circulante entre os tratamentos. Adicionalmente, não só o ganho de peso dos animais pode reduzir quando um animal é submetido a estresse crônico, mas também a composição do ganho de peso pode ser alterada, principalmente pelo evidente aumento da distribuição do tecido adiposo, principalmente na cavidade abdominal (Rebuffé-Scrieve et al., 1992; Peckett et al., 2011).

O estado físico e emocional dos animais e suas correspondentes reações aos manejos podem ter impactos importantes na quantidade e qualidade de carne produzida (Schaefer et al., 2001; Paranhos da Costa et al., 2012). No entanto, são escassos os estudos, em condições tropicais, como da maioria das regiões brasileiras, tratando da relação existente entre a implantação de estratégias para melhorar o bem-estar de bovinos em confinamentos e seus potenciais efeitos sobre o ganho de peso, qualidade das carcaças e da carne. Sendo assim, existem questionamentos constantes entre produtores e técnicos, que adotam o sistema de confinamento para bovinos, sobre quais seriam as melhores técnicas de manejo a serem empregadas, para que problemas sociais, ambientais e de saúde fossem evitados, garantindo melhores condições de bem-estar aos animais e, consequentemente, possibilitar a produção dos animais com critérios éticos e com lucratividade.

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CAPÍTULO 2. Reduced space for outdoor confined beef cattle causes greater environmental impact and increases animal stress and disease

Abstract - The objective of this research was to evaluate the implications of the space availability in feedlot in beef cattle welfare. One thousand, three hundred and fifty bulls were confined during 12 weeks within feedlot pens with three space allowance: 6 (T6), 12 (T12) and 24 (T24) m^2/animal. All animals received the same diet. The first six weeks was called "dry period" and the last "rainy period". Animal welfare were assessed using environment based (dust score and mud depth) and animal based indicators, part of these measurements was carried out with the animals housed in confinement pens by using behavioral (number of animals standing, lying down, or in the feed bunk), comfort (percentage of dirty animals), and health indicators (number of coughs and sneezes per minute, and the percentages of animals with diarrhea, hooves alterations, locomotion problems, tegument alterations, and nasal and ocular discharges), and in the slaughterhouse, evaluating health indicators with macroscopic diagnosis (percentage of animals with bronchitis, emphysema, nephritis and urinary cyst), besides stress indicators, after the collection the adrenal glands (left and right) of 20% of the animals from each treatment, to assess the weight and cortical and medullar areas of them as stress indicators. In general, the indicators of animal welfare showed that the T24 offered better environmental conditions for the finishing phase of beef cattle than the other treatments, evidenced by the lower frequency of occurrence of dust and mud depth ($P < 0.01$), lower percentages of animals with nasal and ocular discharges and locomotion problems ($P < 0.05$), and lower percentage of animals diagnosed with bronchitis, emphysema, nephritis and urinary cyst. It is concluded that the reduction of the space allowance in commercial cattle feedlots increases the stress and impoverish the animal welfare by compromising the health, behaviour and environment.

Keywords: animal welfare, behavior, feedlot, health, stress

Introduction

Over the last few decades, there has been a worldwide trend to decrease the space allowance per animal in intensive livestock farming, which is justified by a reduction in production costs and an increase in the productivity per area, as reviewed by Thornton (2010). However, societal concerns about livestock intensification have been raised which mainly focus on its impact on the environment, food safety, and animal welfare (Vanhonacker et al., 2009; Grandin, 2014).

Considering the environment, limited spaces in cattle feedlot operations usually impoverish the local air quality, increasing air dust and the concentration of noxious gases (e.g., ammonia, carbon dioxide and hydrogen sulfide), and maximize the negative effects of manure and mud accumulation, speeding up pen condition degradation (Gustafsson, 1997; May et al., 2012). The severity of these problems depends on a number of factors; for instance, the amount of mud in feedlot pens is affected by rainfall, facilities' drainage systems, and manure accumulation (Mader, 2011); while air dust condition is directly dependent on the local weather conditions, soil type, and movement of animals and vehicles (West, 2011). Furthermore, high stocking density in cattle feedlot results in social stress, since the animals are not able to avoid competitive encounters (Kondo et al., 1989; Lindberg, 2001; Fregonesi et al., 2007). Such conditions usually lead to chronic stress over time (Fisher et al., 2003), with negative effects on cattle immune function (Jensen and Larsen, 2014) and performance (Fisher et al., 1997; Fraser et al., 2013), due to behavioral, endocrine and metabolic changes (Manson, 2000; Matteri et al., 2000).

To date, the few studies addressing the impact of space allowance on the welfare of confined beef cattle have shown that animals kept in larger spaces display overall better performance and welfare (Kondo et al., 1989; Gygax et al., 2007; Gupta et al., 2007). Nevertheless, most of these studies were conducted with animals maintained in indoors feedlot, with very high stock densities (from 1.2 to 6.0 m^2/animal) and few animals per lot (from 8 to 24 animals). Importantly, to the best of our knowledge, there are no studies addressing the effect of stock density on the health of confined beef cattle in outdoor feedlot.

Outdoor beef cattle feedlots are common in many countries, such as Brazil, Mexico, USA and Canada. In Brazil, most cattle confinement is outdoors, and animals are kept in large lots (from 100-200 animals/lot) with an average space allowance of approximately 12 m²/animal (Souza et al., 2003; Quadros, nd). Although indoor and outdoor confinements may reflect different environment for these animals, both forms of confinement restrict cattle natural behavior, but probably do it in different ways. Therefore, the aim of our study was to evaluate the effects of space allowance on the welfare of outdoor confined beef cattle. To this end, we compared the effects of three different stock densities (6, 12, and 24 m²/animal) on several variables reflecting environmental, behavioral, health and physiological animal welfare indicators.

Materials and methods

This study was approved by the Ethics Committee on Animal Use, from the FCAV-UNESP (CEUA - protocol number 025961/13).

- Local and period of study

The study was conducted in a commercial feedlot in Campo Verde, Mato Grosso State - Brazil (15º32'48" S and 55º10'08" W, 736 meters above the sea level) from August 20 to November 15, 2012, totalizing around 87 days of confinement. The study period was classified as dry (from August 20 to October 5) and rainy period (from October 6 to November 15).

The weather conditions were monitored by measuring black globe temperature (BGT, °C), air temperature (AT, °C) and relative humidity (RH, %), by using a black globe and a digital thermo-hygrometer (Incoterm® - model 7663). Rainfall (mm) was registered systematically using a manual pluviometer. The AT, RH, and BGT were recorded at 20-minute intervals between 7 and 17 h every other day in the first two weeks of study and then weekly until the end of the experimental period. The cumulative amount of rainfall (mm) and the average of the maximum and minimum AT, BGT, and RH over the study period are presented in the Figure 1 A, B and C, respectively, according to the study weeks.

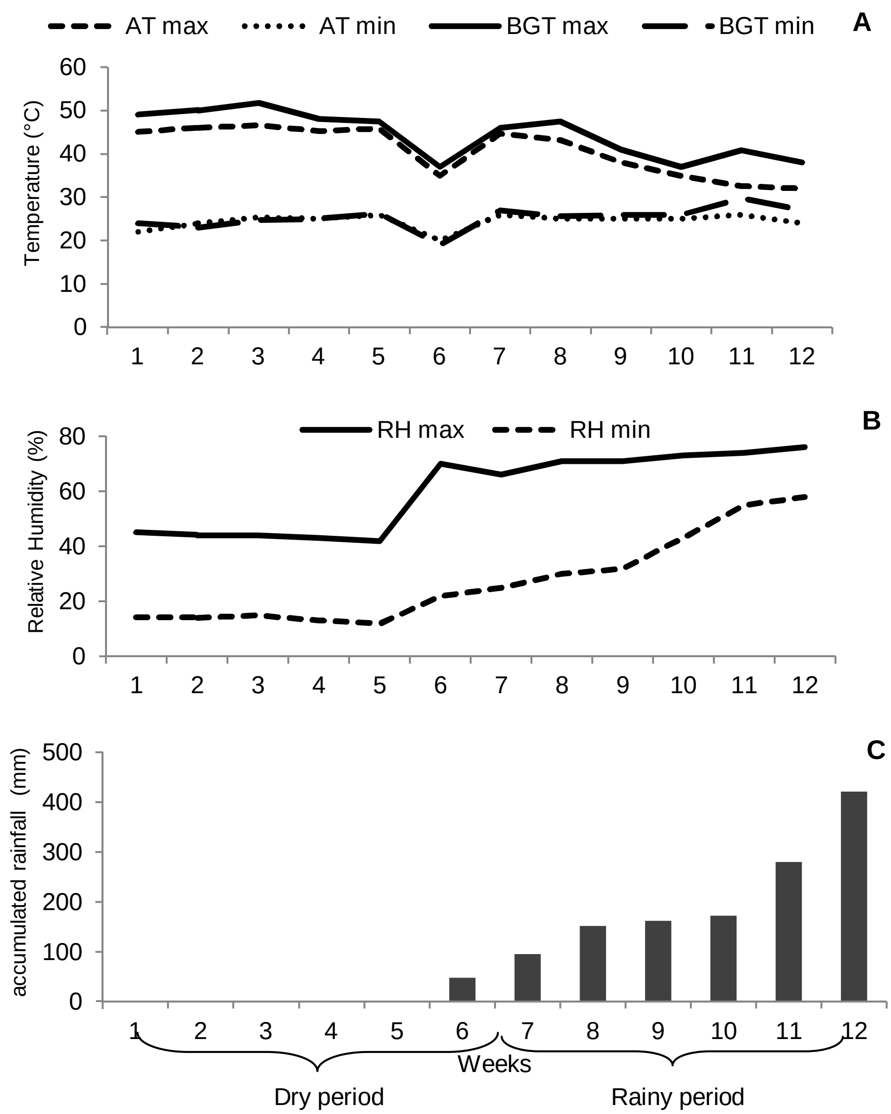

Figure 1. A – Means of the maximum and minimum air temperature (AT) and black globe temperatures (BGT), B - relative humidity (RH) and C - accumulated amount of rain, per week.

- Animals, treatments and facilities

We evaluated 1.350 bulls (450 Nellore and 900 crossed - Angus or Caracu bulls with Nellore cows) with 30 ± 6 months of age and weighing 392 ± 46 kg. All animals were individually identified with numbered ear tags.

The animals were transported to the farm two weeks before the beginning of the study, and kept on *Brachiaria ruzizienses* pasture with free access to mineral supplement and water. At day 0 the animals were weighed, vaccinated (against clostridial diseases) and dewormed (using Doramectin 1%). Nine lots with 150 animals (one with Nellore and two with Crossed cattle) were assigned to three treatments, considering the space allowance of 6 (T6), 12 (T12) and 24 (T24) m² per animal. We determined the applied spaces allowance by halving and doubling the area commonly used in commercial Brazilian feedlots.

The confinement pens were enclosed by fences. All pens surfaces had approximately 5% slope, and masonry feed bunk and water trough. The water troughs measured about 1.5 meters of diameter, being common for two pens, and were cleaned three times a week. There were 50 meters feed bunk lines per pen (33 cm per animal). The variation in the pen areas was made changing their length, being 18, 36 and 72 m for treatments of 6, 12 and 24 m²/animal, respectively. The layouts of the feedlot pens are shown in Figure 2.

- Animal welfare indicators

The welfare of the animals was assessed considering environment (air dust intensity and depth of mud) and animal based indicators (by using behavioral, health and physiological indicators). The assessments were performed by previously trained technicians, after achieving at least 80% of correspondence between their measurements. All observers wore personal protective equipment during data collection.

<u>Environment-based welfare indicators</u>

Dust intensity

The dust intensity was evaluated on alternate days during the first two weeks of the study and thereafter weekly. The evaluations were performed in the period between 07:00 and 17:00 h, every 20 minutes intervals, registering one of the following scores: (0) no dust, (1) presence of dust which does not difficult the observer to see the animals and breath, (2) presence of dust which hinders the observer to see the animals and breath, and (3) presence of dust which obstructs the observer to see the animals and makes breathing difficult.

Mud depth

The mud depth was measured at 9 points of the pens, two points (1 and 2) in front of the pens (2.5 meters from the feed bunk), two points in the middle of the pens (3, 4), two points at the back of the pens (2.5 meters from the fence) (5, 6) and three points (7, 8 and 9) around the water trough, as shown in Figure 2. The measurements were carried out using a wood stick that was introduced in the mud, and then using a tape to measure the height of the mud marked at the stick; after each measure the stick was washed. These measures were always taken at 16:00 h by the same person, and were made every other day for the first two weeks of the study and weekly thereafter.

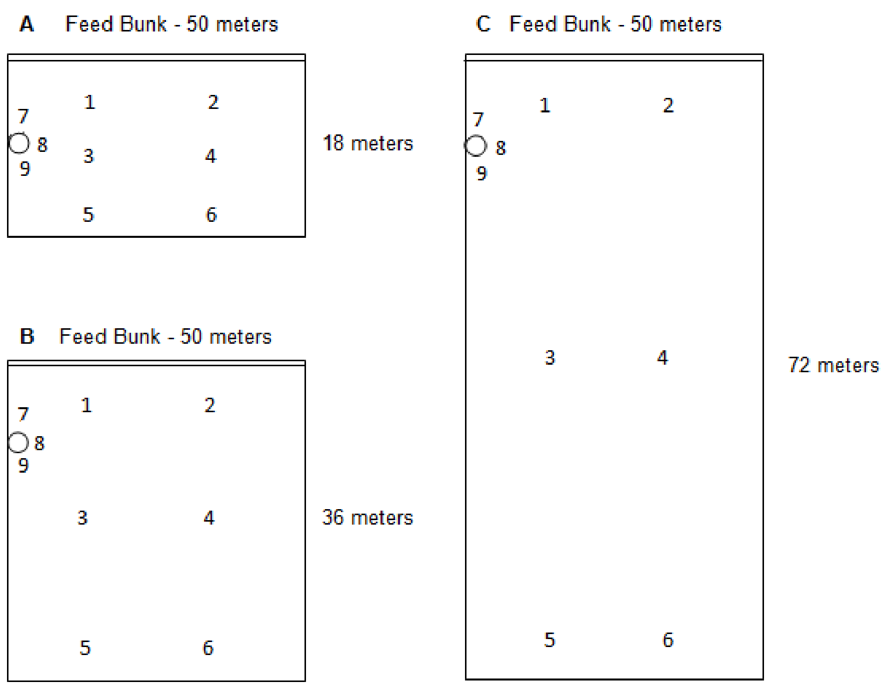

Figure 2. Layouts of the feedlot pens showing the points where the mud depths were measured in the pens with 6 (A), 12 (B) and 24 m²/animal (C). Points 1 and 2 in front, 3 and 4 in the middle, 5 and 6 at the back of the pens and 7, 8 and 9 around the water trough (O).

Animal-based welfare indicators

Behavioural indicators

Body posture and the position that the animals occupied in the pen were used as behavioral indicators of cattle welfare. Observations were made every other day in the first two weeks of study and thereafter weekly. The assessments were performed by the same person in each pen, being recorded at 20 minute intervals from 7:00 to 17:00 h, by recording the number of animals standing and lying in front, middle and back of the pens, as well as the number of animals attending the feed bunk. The number of animals attending the feed bunk was not added to number of animals standing. The areas in "front" of the pens were equals for all treatments (5.0 x 50 m). The resulting area, subtracting the "front" from total area, were divided into two equal parts, and characterized as "middle" and "back". To facilitate observation, we demarcate the beginning and end of the areas painting the fence posts with white paint.

Health indicators

Health assessment were performed every other day during the first two weeks of the study and weekly thereafter, always beginning at 08:00 and following the same pens´ order by the same observer, who was positioned in front of each pen, recording data from 10% of the animals of each lot (randomly defined).

The health indicators were based in the Welfare Quality Protocol® (2009), and the following scores were used: locomotion (0 = animal walks with equal times between each step and distributes the body weight in all four feet, 1 = the animal does not present balanced distribution of body weight in all four feet or time between each step is not equal, the animal limps but can get around with four feet on the floor, and needs to be examined and treated, and 2 = the animal is reluctant to support at least one of the members on the ground when walk, requiring urgent attention and care; tegument alterations (0 = the animal does not present any tegument alteration, 1 = some area in the animal's body is without hair, and 2 = the animal presents lesion or edema in its body; hoof alterations (0 = no alterations and 1 = alteration in length or irregular shape in, at least, one of the shells). We also evaluated some clinical signs of diseases, recording for each lot the number of sneezes and coughs per minute, and the percentages of animals with nasal and ocular discharge, breathing difficulty (animals with rapid respiratory rate and wheezy breath) , diarrhea and bloating (1 = presence and 2 = absence of clinical signs).

At the end of the experimental period, all animals were slaughtered at a commercial slaughterhouse, and a diagnosis of health problems was carried out by examining macroscopically the kidneys and lungs of each animal. These assessments were performed by veterinarians of the Federal Inspection Service (SIF), from the Brazilian Ministry of Agriculture, Livestock and Food Supply, following the guidelines of the Department of Animal Products Inspection (BRASIL, 2007).

Comfort indicator

To evaluate the comfort of the animals we used the measure of body dirtiness as an indicator. This measurement was based in the Welfare Quality Protocol® (2009) by using the following scores: 0 = totally clean animal; 1 = animal with up to 25% of the body dirty, 2 = animal with between 25 to 50% of its body dirty, and 3 = animal with more than 50% of its body dirty.

Stress indicators

The adrenal glands (right and left) of 20% of the animals (randomly selected from each treatment) were collected after slaughter, at the time of evisceration. The glands were dissected (for fat and other tissues removal), identified, placed in plastic bags and refrigerated at 4 °C. After 24 hours, they were weighed individually on a precision scale, and then frozen at -18 °C.

Every frozen adrenal were inserted gland in a plastic bag (previously identified), with fixative solution of *Bouin* for 24 hours. After being removed from this solution, the adrenal glands were dried with paper towels, and cut them lengthwise using a bistoury. Then, the adrenals glands were placed individually on clear plane surface with identification and a ruler. All samples were photographed three times with a digital camera supported on a tripod, maintaining the lens parallel to the surface. The software Image J® and digitizer table (Bamboo®) were used to measure the longitudinal and transversal axis (cm) of each gland, and to calculate the total and cortical area (cm^2), and by difference the medullar area (cm^2) was estimated. The adrenal gland weight and medullar and cortical areas were used as stress indicators.

- Diet and feeding management

The animals were fed four times a day, twice in the morning (07:30 and 10:00) and in the afternoon (14:30 and 16:30). Generally the animals received 40% of the total amount of food at the last feed of the day, and 20% in each of the other three feeds.

Two diets were used during the study period, the "adaptation", offered in the first 25 days of confinement, and the "finishing", offered from the 26th day until the end of the experiment, their compositions are shown in Table 1.

Table 1. Composition (% of DM) of the "adaptation" and "finishing" diets offered to the cattle in all treatments during the study period

	Adaptation	Finishing
Ingredient		
Corn silage	44.03	14.00
Cotton hulls	00.00	12.50
Corn residue*	07.09	10.20
Milled corn	26.18	40.30
Cotton seed cake	12.67	12.38
Soybean skin	08.13	08.84
Other**	01.90	01.78
Total	100.00	100.00

DM = Dry matter; Dry matter intake = 2.4% live weight.
* Residue from corn storage
** 14.93% mineral salt, 85% urea and 0.074% sodium monensin.

- Statistical analyses

The behavioral and the health variables were expressed by percentages of animals displaying each behavior or presenting the signs of diseases. Furthermore, the variables related to the measurements of adrenal gland were characterized by the sum of the values of the right and left glands, adjusting these values (for each individual) to the hot carcass weight, being expressed in g (weight) and cm^2 (cortical and medullar areas) per 100 kg of carcass weight.

After the achievement database consistency assessment, the extreme values were excluded by applying the criterion of average ± 3 standard deviations. The normality was checked for all dependent variables considered continuous (mud depths, behavioral indicators, comfort and *ant-mortem* health indicators, adrenal gland weight and medullar and cortical areas) using the Kolmogorov-Smirnov test. The *post-mortem* health indicator was considered as binomial distribution. All data were analyzed using SAS software (SAS Inst. Inc. Cary, NC) and the results were considered statistically different when $P < 0.05$.

To assess whether the frequency of dust score depended on the treatments, the chi-square test was applied, using the Proc Freq. To evaluate the effect of treatments in the mud depths, behavioral, comfort and health indicators, a repeated measures analysis of variance (ANOVA) was applied using Proc Mixed, but before we tested witch covariance matrix may be used for each variable. We considered the fixed effects of treatment, period, week within period, and the interaction between treatment and period. Genetic group was included in the model as a random effect and also the effect of lot within treatment, which was the *subject* on which repeated measures across weeks were taken. Mean comparisons were performed by Tukey test. The regression coefficients of the variables for each treatment were compared using orthogonal contrasts, and all of them were linear and significant ($P < 0.05$). The associations between the environmental welfare indicators were estimated by using the Pearson correlation coefficient, by applying the Proc Corr.

The effects of treatments on the stress indicators (adrenal gland weight and medullar and cortical areas) were assessed using ANOVA with Proc Mixed, We considered the fixed effect of treatment, and the genetic group was included in the model as a random effect. Mean comparisons were performed by Tukey test.

The effects of treatments (feedlot space allowance) on the occurrences of bronchitis, pulmonary emphysema, nephritis and renal cyst were analyzed by logistic regression using the GENMOD procedure of SAS. The binomial data distribution was assumed with probit link function to an adjacent normal distribution. The Ratios of the odds were calculated to obtain information regarding the possibility of developing each disease between classes of space allowance treatments. In this analysis the treatment 24 m²/animal was assumed as reference category (RC).

Results

Environment- and animal-based welfare indicators were used to assess the effects of three space allowances on the welfare of beef cattle kept in an outdoor feedlot under tropical conditions. We hypothesized that beef cattle welfare would improve with increasing feedlot space allowance.

Environment-based welfare indicators

There was a significant difference in air dust content among treatments (chi-square test, DF = 6, χ^2 = 49.02, and P < 0.01), with T24 yielding the best conditions (i.e., the lowest amount of dust and the highest frequency of “0” scores).The worst air dust conditions (scores 2 and 3) were infrequent in all treatments (see Figure 3)

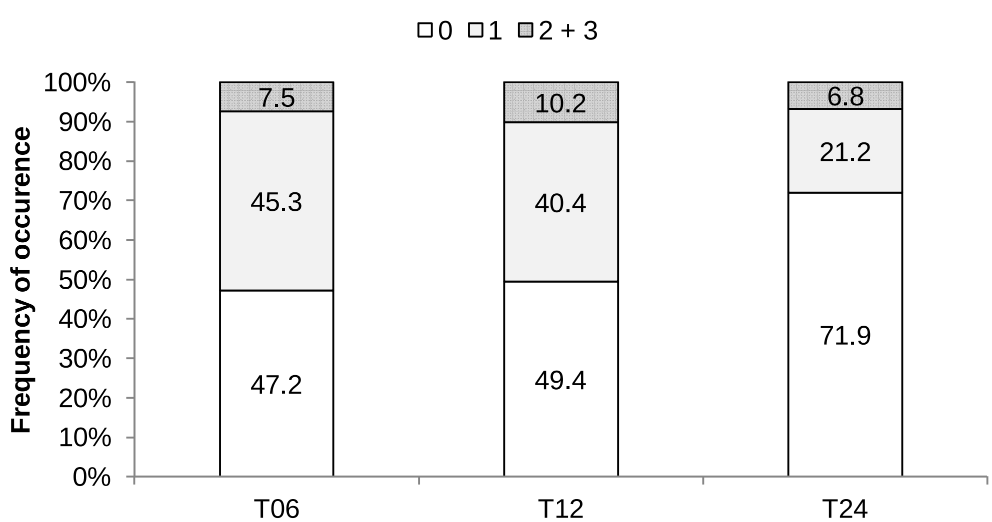

Figure 3. Percentages of dust score occurrence per treatment.

All mud depth measurements (front, middle, back and around the water trough) were affected by the interaction between treatments and periods (P < 0.01). In general, mud was deeper for T6 than for T24, except for the middle and back measurements during the dry period and around the water trough in both periods (Table 2).

Table 2. Treatment-period interaction means (±SE) for mud depth (cm) measured in front, middle, back and around the water trough of the feedlot pens

Local and period	Treatment		
	T6	T12	T24
Front			
Dry	4.66 (0.68) ^{xa}	3.49 (0.63) ^{xab}	2.46 (0.54) ^{xb}
Rainy	10.61 (0.66) ^{ya}	8.51 (0.59) ^{yab}	7.19 (0.66) ^{yb}
Middle			
Dry	2.52 (1.52) ^{xa}	4.87 (1.46) ^{xa}	2.78 (1.36) ^{xa}
Rainy	21.56 (1.56) ^{ya}	13.89 (1.39) ^{yb}	8.93 (1.51) ^{yb}
Back			
Dry	4.83 (1.12) ^{xa}	3.50 (1.12) ^{xa}	0.16 (1.19) ^{xa}
Rainy	17.17 (1.14) ^{ya}	14.39 (0.90) ^{ya}	5.28 (1.51) ^{xb}
Water trough			
Dry	4.80 (2.57) ^{xa}	6.83 (2.52) ^{xa}	5.17 (2.45) ^{xa}
Rainy	18.49 (2.93) ^{ya}	13.26 (2.54) ^{ya}	11.97 (2.85) ^{ya}

Means followed by x,y across periods and a,b across the treatments did not differ statistically (Tukey test, P > 0.05).

Animal-based welfare indicators

Behavioural indicators

Lying and standing behaviours were affected by period ($F_{1,\ 67.9}$ = 1.47; P < 0.05 and $F_{1,\ 68.1}$ = 3.99; P < 0.05, respectively), but not by treatment or period-treatment interaction, with lower relative frequencies of cattle lying and standing during the dry period (32.55 ± 1.60 and 52.23 ± 1.80% of the animals, respectively) than during the rainy period (33.54 ± 1.52 and 55.50 ± 1.70% of the animals, respectively). On the other hand, there was a significant interaction between treatments and periods for the relative frequencies of animals attending the feed bunk ($F_{2,\ 69,3}$ = 8.20; P < 0.01). Significant lower means of feed bunk attendance were observed during the rainy period for all treatments (P < 0.01), with more pronounced differences between periods for T6 and T12 (Table 3).

Table 3. Means (±SE) of the percentages of animals (%) attending the feed bunk by treatment-period interaction

Period	Treatment		
	T6	T12	T24
Dry	17.12 (1.08) ^{xa}	14.22 (1.05) ^{xa}	13.94 (1.01) ^{xa}
Rainy	9.28 (1.09) ^{yb}	9.88 (1.05) ^{yb}	11.67 (1.07) ^{ya}

Means followed by x,y across periods and a,b across the treatments did not differ statistically (Tukey test, P > 0.05).

The percentages of animals lying in the front, middle and back of the pens were affected by treatments and periods in different ways, which we propose could be due to the variation in mud depth within pens over the feedlot periods, as presented below. The percentage of animals lying in the front was affected by treatment ($F_{2,\ 4.94}$ = 6.31; P < 0.05) and period ($F_{1,\ 55.6}$ = 4.76; P < 0.05), and a higher mean (P < 0.05) was observed for T24 (30.99 ± 2.05%) relative to T6 and T12 (11.81 ± 2.11% and 18.38 ± 2.03%, respectively), which did not differ from each other (P > 0.05); and a lower mean (P < 0.05) was observed for the dry (17.19 ± 1.62%) relative to the rainy period (23.61 ±1.54%). On the other hand, the percentage of animals lying in the back was significantly affected by the treatment-period interaction ($F_{2,\ 54.3}$ = 3.91, P < 0.05). The mean for T24 was lower than for the other treatments in the dry period, and it was the only treatment that did not differ between periods (P > 0.05), as shown in Table 4. No significant effects of period or treatment were found for lying in the middle of the pen (P > 0.05).

Table 4. Means (±SE) of percentage of animals lying in the back of the feedlot pens by treatment period interaction

Period	Treatment		
	T6	T12	T24
Dry	49.40 (5.33) ^{xa}	48.73 (5.38) ^{xa}	17.78 (5.56) ^{xb}
Rainy	31.68 (5.78) ^{ya}	39.48 (5.32) ^{ya}	22.17 (5.15) ^{xa}

Means followed by x,y across periods and a,b across the treatments did not differ statistically (Tukey test, P > 0.05).

The average number of dirty animals did not differ among treatments (P > 0.05), with 37.50 ± 3.87, 31.01 ± 3.74 and 29.15 ± 3.71% of dirty animals for T6, T12 and T24, respectively, but it did differ among periods ($F_{1, 42.1}$ = 96.83; P < 0.01), with a progressive increase of dirty animals over the experimental time period (Figure 4), resulting in approximately five times the percentage of dirty animals by the rainy period (11.58 ± 3.10% *vs.* 55.53 ± 3.02%, for dry and rainy periods).

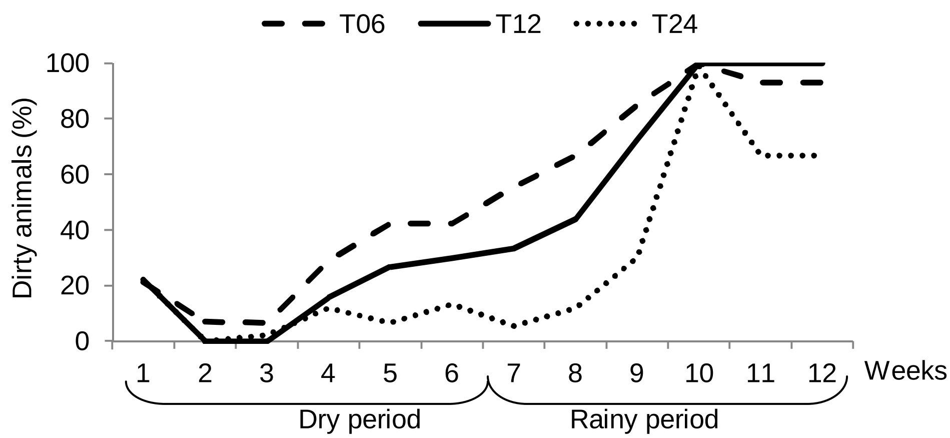

Figure 4. Percentages of dirty animals per treatment over the feedlot period.

The mud depth at the back of the pens presented the highest correlation with the percentages of animals attending the feed bunk (r = -0.41; P < 0.01), lying (r = 0.27; P < 0.02), and dirty animals (r = 0.72; P < 0.01).

Health indicators

We evaluated ten *ante-mortem* (coughing, sneezing, nasal and ocular discharges, diarrhea, ruminal tympany, roof and integument alterations, locomotion deficits and breathing difficulty) and four *post-mortem* (bronchitis, pulmonary emphysema, urinary cist and nephritis) health indicators. While we did not observe any cases of ruminal tympany during data collection, there were two cases in the T6 and one in the T12 recorded in the farm database.

During the dry period and the first three weeks of the rainy period, we did not record any cough, which precluded any statistical analyses for this trait. Nevertheless, we noticed an important numerical variation in frequency of coughs per minute among treatments, with means of 1.67, 0.33 and 0.00 for T6, T12 and T24, respectively (Figure 5B).

There was a significant interaction between treatment and period for the number of sneezes per minute ($F_{2, 74} = 6.41$; $P < 0.01$). During the dry period, T6 animals had more sneezes/min than animals in the other treatments, while in the rainy period, no sneezes were recorded for animals in any of the treatments (Figure 5A).

Differences in the percentages of animals with nasal and ocular discharges were found between periods ($F_{1, 72.4} = 4.59$; $P < 0.05$) and among treatments ($F_{2, 72} = 5.9$; $P < 0.01$). Means for both traits were significantly lower for T24 animals than those for the other treatments, and both symptoms were less frequent during the rainy period ($P < 0.05$), as shown in Figure 5C and 5D.

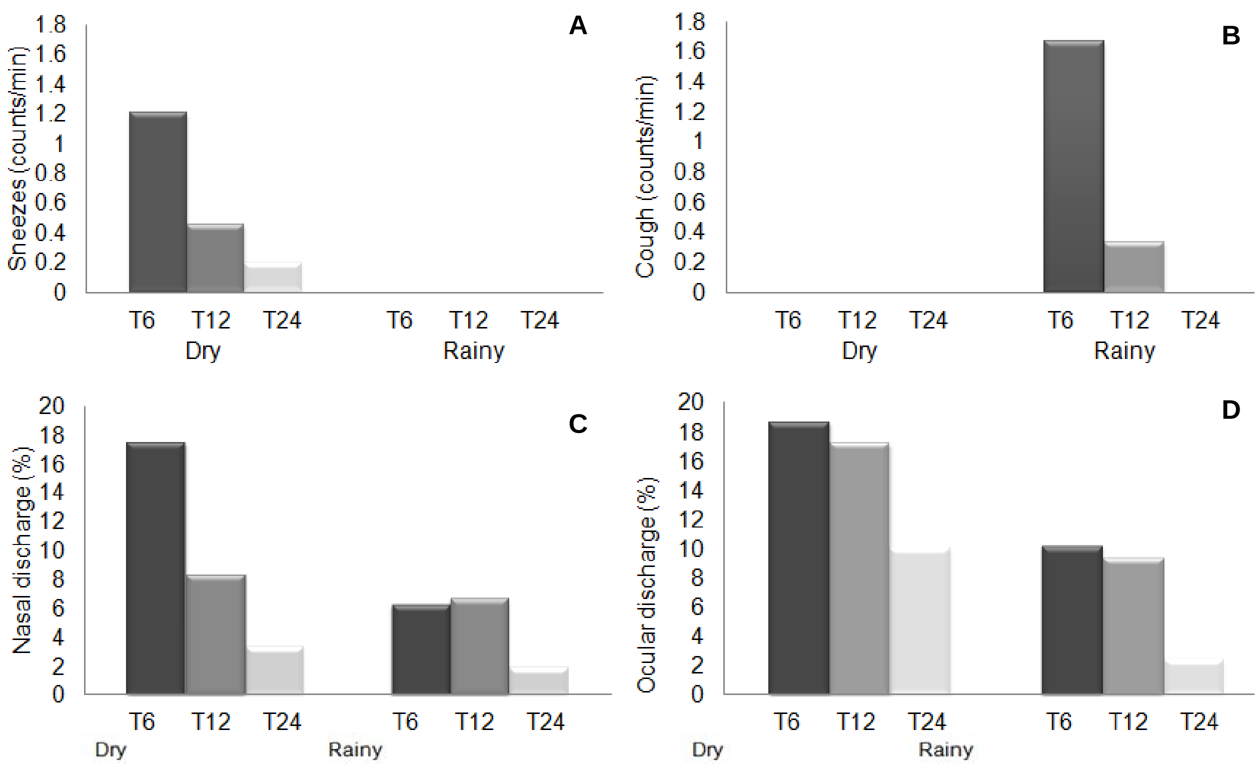

Figure 5. Means of sneezes (a) and coughs (b) per minute, and percentages of animals with nasal (c) and ocular (d) discharges by treatments and periods.

Due to excessive amounts of mud during the last three weeks of the rainy period, it was not possible to record the scores for locomotion, tegument and hoof alterations, and then the statistical analyses for these traits were conducted using data only from the first three weeks of the rainy period. There was a significant effect of both treatment and period for the locomotion score ($F_{2, 69.1} = 1.90$; $P < 0.05$, and $F_{1, 53.1} = 2.23$; $P < 0.05$, respectively). Diarrhea was only affected by treatment ($F_{2, 62.0} = 1.68$; $P = 0.05$) and hoof alteration only by period ($F_{1, 57.0} = 10.14$; $P < 0.01$). No significant effects of treatment or period were observed for tegument alteration or breathing difficulty. Means for all variables are listed in Table 5. No animals displayed severe locomotion deficits (score 2).

T6 animals presented the highest odds ratio of developing all diseases analyzed, and only in the case of bronchitis, T12 animals had a higher risk than the reference class animals (T24), as presented in Table 6.

Table 5. Means (±SE) of the percentage of animals with locomotion deficits (LD), tegument alteration (TE), hoof alteration (HA), diarrhea (DI) and breathing difficulty (BD) by treatments and periods

	LD (%)*	HA (%)*	TE (%)*	DI (%)	BD (%)
Treatment					
T6	4.07 (3.95)^{a}	2.95 (1.55)^{a}	3.98 (1.45)^{a}	1.38 (0.61)^{a}	0.48 (0.36)^{a}
T12	5.09 (2.93)^{a}	1.23 (1.05)^{a}	2.05 (1.41)^{a}	0.64 (0.55)^{b}	0.50 (0.33)^{a}
T24	0.78 (2.95)^{b}	0.93 (1.04)^{a}	1.93 (1.41)^{a}	0.47 (0.55)^{b}	0.20 (0.33)^{a}
Period					
Dry	1.48 (2.25)^{a}	1.12 (1.15)^{a}	1.28 (1.32)^{a}	0.99 (0.43)^{a}	0.44 (0.25)^{a}
Rainy	5.48 (3.11)^{b}	3.23 (1.21)^{b}	1.03 (1.36)^{a}	0.67 (0.51)^{a}	0.35 (0.30)^{a}

Means followed by the same letters in the columns across treatments and periods did not differ statistically by Tukey test (P > 0.05). *statistical analyses for LD, HA and TE were conducted using data until the first three weeks of the second period.

Table 6. Numbers and percentages of animals presenting clinical *post-mortem* signs of bronchitis, pulmonary emphysema, nephritis, and urinary cysts and their respective *odds ratios,* confidence intervals and chi-squares per treatment

Disease and treatment	N	%	Odds ratio	Confidence interval	$\chi2$
Bronchitis					
T6	153	34.02	14.88*	8.58 – 25.79	92.71
T12	65	14.44	4.90*	2.75 – 8,76	29.02
T24	15	3.33	1.00	RC	.
Pulmonary emphysema					
T6	11	2.47	5.61*	1.23 – 25.53	5.00
T12	2	0.44	1.00	0.06 – 16.12	0.00
T24	2	0.44	1.00	RC	.
Nephritis					
T6	28	6.22	3.67*	1.65 – 8.17	10.21
T12	13	2.91	1.65	0.67 – 0.25	1.20
T24	8	1.80	1.00	RC	.
Urinary cysts					
T6	43	9.58	6.69*	2.97 – 15.03	21.13
T12	10	2.24	1.43	0.55 – 3.82	0.53
T24	7	1.53	1.00	RC	.

Odds ratio values followed by * in the columns differ statistically from the RC (χ^2 test, P > 0.05). N = number of animals; (%) = percentage of animals and RC = reference class.

Stress indicators

The adrenal glands weight and medullar and cortical areas were used to assess the physiological status of the animals in relation to stress. There were no differences in these measurements when we compare the left and right adrenal glands; therefore, we decided to present the results as the means of the cortical and medullar areas and the sum of glands weights. Adrenal cortical area and weight were affected by treatment ($F_{1, 113} = 10.48$ and $F_{2, 125} = 9.95$; $P < 0.01$ for both), with T24 animals displaying the lowest means for both traits (Table 7).

Table 7. Means (±SD) of adrenal gland medullar (MA), cortical area (CA) and weight (AW), by treatments, corrected for carcass weight

Treatment	MA (cm²/100 kg carcass)	CA (cm²/100kg carcass)	AW (g/ 100kg carcass)
T6	3.59 (0.99)[a]	2.40 (0.50)[a]	8.87 (1.13)[a]
T12	3.89 (0.63)[a]	2.27 (0.43)[a]	8.77 (1.12)[a]
T24	3.73 (0.67)[a]	2.11 (0.34)[b]	8.22 (1.20)[b]

Means followed by the same letters in the columns did not differ statistically (Tukey test, P > 0.05).

Discussion

In this study, we compared three different space allowances (T6, T12 and T24) for outdoor feedlot beef cattle and observed that increasing space allowance resulted in progressively more comfortable environment and healthier animals, leading to overall better animal welfare.

As expected, air dust was a cause for concern only during the dry period, while mud accumulation occurred in both periods, but mostly during the rainy period. For both of these indicators, the best environmental conditions were observed for T24, and extreme mud accumulation was found for T6. These differences are probably related to the variation of stocking density among the treatments, as reported by Bonifácio et al. (2012) and Mader (2011) for mud and by West (2011) for air dust. There is empirical evidence that, besides depending on the soil moisture condition, air dust and mud accumulation are highly dependent on the cattle foot traffic on the pen surface (West, 2011; Schwartzkopf-Genswein et al., 2012).

During the rainy period, we observed a reduction in the percentage of animals attending the feed bunk, as well as an increase in the percentage of animals lying and standing. A reduction in feed bunk attendance throughout the feedlot period is expected, given the increase in the diet's energy content, what is explained by Mertens (1994) as a consequence of physiological satiety. However, these behavioral changes from the dry to the rainy period may also be attributed to the reduction in feed intake caused by the adverse pen conditions, probably mainly due to mud accumulation, as previously reported (Morrison et al., 1970; Mader, 2011). In this case, the reduction in the food intake can be attributed to psychogenic regulation (Mertens, 1994). According to Mader (2011), under such environmental conditions, maintenance requirements can increase and, as a result, cattle performance and welfare can be compromised in the long-term. In this study, we observed that this detrimental situation had an increasingly strong effect as space allowance decreased, since the reduction in animals attending the feed bunk during the rainy period (relative to the dry period) was 45.79% for T6, 30.52% for T12 and 16.28% for T24.

The percentage of animals lying in the front and in the back of the feedlot pens changed across study periods and treatments. During the dry period, T6 and T12 animals lay mostly in the back of the pen, while during the rainy period they chose mostly the front to lie down. T24 animals, on the other hand, lay equally across the front, middle and back of the feedlot pens for both periods. One probable explanation for the behavior observed in T6 and T12 animals during the rainy period is mud accumulation over time, which increased substantially, reaching more than 14 cm in the back of the pen for both treatments.

Lying behavior is a frequent indicator of cattle comfort (Haley et al., 2001; Fischer et al., 2003), and cattle often lie while resting and ruminating (Fraser, 1983). The selection of places to lie depends on two main factors, the comfort of surfaces (Haley et al., 2001) and social interactions (Fraser, 1983). Despite the fact that pen surface degradation over time occurred across all treatments, the percentage of animals lying increased from the dry to the rainy period, reflecting the importance of this behaviour for the cattle.

Regardless of the better pen conditions (with shallow mud) and the distinct pattern of pen use presented for T24 animals, we did not observed any difference across treatments in the percentage of dirty animals (scores 2 and 3). However, a visual analysis of Figure 3 shows clear differences between T24 and both T6 and T12 from weeks 5 to 8. It is important to point out that there was a rainstorm (around 90 mm) one day before the assessment on week 10, when all animals were rated as dirty, as shown in Figure 3. These results suggest that, except for extreme rainy conditions, the increase in space allowance for confined cattle can improve body hygiene. A similar trend was observed by Gygax et al. (2007), but their study was conducted with cattle confined in smaller indoor space allowances (ranging from 2.5 to 4.0 m^2/bull).

It is well known that challenging environments expose individuals to stress, and the effects of certain stressors are accumulative (Selye, 1952; Morbeg, 2000). Under prolonged stress situations, these stressors can cause physiological and morphological changes, as adrenal gland hypertrophy, which has been shown for some mammal species (Shively and Kaplan, 1984; Ulrich-Lay et al., 2006; Harvey, 2014). In the present study, we observed lower cortical area and weight of the adrenal gland for T24 cattle, indicating a lower chronic stress response in this group compared to T6 and T12 animals. One possible explanation for this finding is that lower space allowance would expose animals to unpleasant environmental factors (such as dust, noxious gases, mud, uncomfortable surfaces to lie on; Mader, 2011; West, 2011), as well as social tension (Bouissou et al., 2001). Thus, under challenging conditions, greater adrenocorticotropin hormone (ACTH) concentrations are constantly released, over stimulating the adrenal cortex, which can increase its area and gland weight (Ulrich-Lai et al., 2006; Harley, 2014). We believe that this is the first report showing that decreasing space allowance for feedlot cattle can lead to adrenal gland hypertrophy.

Other relevant and negative consequence of chronic stress include the organism immunosuppression (Franci, 2005; Carroll and Forsberg, 2007; Ackermann et al., 2010), and consequently, a predisposition to illness. In this study, we observed a greater incidence of clinical signs of disease for T6 and T12 animals (Figure 4). The occurrences of sneezes and ocular and nasal discharges were greater in the dry period, being crescent as the space allowance reduced. Differently, the occurrence of coughs was inexistent for all treatments in this period. We suggest that the greater concentration of air dust in the dry period can be responsible for such events, added to the probable stress caused by the entrance on feedlot, where many of natural behaviours are suppressed, the managements are different and important environmental resources are absent or restrict (Fraser, 1983, 2013; Lee, 2013; Averós, 2014). According to Nikunen et al. (2007), Griffin et al. (2010) and Lechtenberg et al. (2011), nasal and ocular discharges, sneezes, coughs and fever are typical symptoms of bovine respiratory disease (BRD). Edwards (2010) affirmed that the BRD is a multifactorial disease caused by environmental opportunist infectious agents, that benefit from suppressed and overwhelm immune system in susceptible cattle. The same author suggested that immune-compromised cattle, previously exposed to infectious agents, as the bovine diarrhea virus, are more likely to develop BRD as a secondary infection, what could explain the higher occurrences of sneezes, nasal and ocular discharges concomitantly with the higher percentage of animals presenting diarrhea for T6 than for T12 and T24.

In severe untreated cases, the BRD can compromise not only the upper respiratory tract, but also reach the lungs (Thompson et al., 2006). In the present study, the occurrence of cough was limited to the rainy period, being predominant for T6, with a very low occurrence for T12 and none for T24. In this period the others respiratory symptoms decrease, probably due to the improvement of air quality. However, the high amount of mud accumulated on the rainy period could be characterized as a risk factor to aggravate the cases of respiratory infections already existent, mainly for T6. This assumption was partially confirmed by the post-mortem findings, showing higher risk of lung diseases for T6 than in the other treatments. Serious implications of respiratory diseases are the impoverishing of animal welfare and also the reduction on average daily gain for feedlot cattle, as shown by Snowder et al. (2006) and Thompson et al. (2006).

Other health problems commonly related to uncomfortable environmental conditions are the locomotion deficits and hoof alterations (Somers et al., 2005; Shearer et al., 2012). Several studies related the occurrence of hoof alterations in feedlot cattle with the high energy concentration in the diet (Greenough et al., 1990; Lean et al., 2013). However, in our study all animals were fed with the same finishing diet, with around 80% of concentrate. Thus, the differences found among the three treatments on the percentage of locomotion deficits could be attributed to other environmental factors and immunological status of the animals. The mud accumulation is a recognized risk factor for lameness, injury, hoof-related diseases and, depending on the mud depth, it can also cause difficulties to walk and lay down (Schwartzkopf-Genswein et al., 2012). This can explain, in part, the greater percentage of animals with locomotion deficits and hoof alterations in the rainy period compared to dry, as well as the prevalence of locomotion deficits for T6 and T12. Although the non-significant effect of treatments on hoof alteration, the percentage of animals affected in T6 was twice than T12 and almost three times greater than T24. The lameness compromise cattle welfare in several aspects, mainly because of pain, accidental traumas, psychological stress, and difficulty walking, affecting the maintenance (as lying, feeding and drinking) and the social behaviors (as exposure to bullying and agonistic interactions) (Somers et al., 2005; Shearer et al., 2012; Shearer et al., 2013). In general, these conditions are debilitating and decrease the feed intake and body condition and also overwhelm the immunological system, reducing the resistance to infectious diseases (Eicher et al., 2013; Huxley, 2013). All these set of implications will be more severe as the space allowance decreases, being expected that T6 and T12 animals experience poorer welfare than T24, given their worse locomotion ability.

We also found higher risk of kidneys problems for animals kept in lower space allowance (T6). Our main hypothesis is that the physiological bases for these diseases are not only de reduction of immunity, but also the increased activity of the system rennin-angiotensin-aldosterone combined with other functional and behavioral factors that, according Franci (2005), contribute to cardiovascular and renal disorders.

Conclusion

Our results show that decrease the space allowance for beef cattle in commercial feedlot increases the stress and reduces the animal welfare, by compromising the environment and animals' health and behaviour. The results also indicate that special attention should be paid in looking for more sensible indicators, since some of them (as behavior and comfort indicators) did not show difference between treatments, probably due the influence of other environmental factors than space allowance. Furthermore, the *post-mortem* health and physiological indicators displayed well that the problems with the feedlot cattle welfare are more severe than we are capable to see. Additionally, *post-mortem* diseases indicator and the adrenal size and/or weight should be assessed after cattle slaughter under real or experimental condition, because sometimes the animals seems healthy but theirs organisms are daily fighting against a stressor, trying to adapt, leading to a higher costs of maintenance.

We conclude that the reduction in allowance for feedlot cattle can causes higher environmental impact, changes in the use of space by the animals over the time, and increases animal stress and diseases, resulting in a condition that impoverish the animal welfare.

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CAPÍTULO 3. Is the space availability really important for the feedlot beef cattle performance?

Abstract - The implications of space availability in the feedlot cattle performance were studied using 1.350 beef cattle (30 ± 6 months and 392 ± 46 kg) kept in three different space allowances, 6 (T6), 12 (T12) and 24 (T24) m^2/animal, during 12 weeks. The animals were fed with the same diet, and were weighed in the beginning, after 35 days, and in the end of the experimental period to assess the daily weight gain for the first (Dwg1), second (Dwg2) and total period (Dwgt). The carcass weight (Cw), bruise occurrences, carcass fat covering and meat pH were assessed in the slaughterhouse. The adrenal glands (left and right) of 20% of the animals from each treatment, to assess their weight as stress indicator. T24 showed higher mean of Dwgt ($P < 0.01$). The Cw differed between treatments ($P = 0.05$), with no difference between T24 and T12, and lowest value for T6. Although, the significant difference for the distribution of the fat covering score, and T6 have shown highest mean for meat pH ($P < 0.05$), all treatments displayed means within the range that is expected to ensure the meat quality. The mean number of new bruises per carcass was lowest for the T24 ($P < 0.01$), but did not differ between the T6 and T12. The mean number of old and total bruises per carcass was higher in T12 ($P < 0.01$) than T24 and T6, which did not differ from each other. The occurrence of superficial bruises was different for the three treatments ($P < 0.01$), being lowest for the T24 followed by T6 and T12. The mean number of muscular bruises per carcass was lowest for T6 ($P < 0.01$), however T24 and T12 did not differ from each other. The adrenal weight were affected by treatment ($P < 0.01$), and had association with the performance variables and carcass and meat quality ($P < 0.01$). The adrenal gland weight was lowest for T24 and associated only with Cw. However, highest adrenal gland weights were associated with Dwgt, Cw, total number of bruises and muscular bruises occurrence for T6, and Dwg2, Dwgt, Cw and carcass fat covering for T12. Our results show that the reduction of beef cattle space allowance in commercial feedlot increases the stress affecting directly the animal performance.

Keywords: animal welfare, confinement, quality, stress, weight gain

Introduction

The importance of genetics, health and nutrition in the feedlot cattle performance is evident (Vaz et al., 2013; Hay et al., 2014, Oliveira and Millen, 2014). However, another relevant, but little studied factor, is the space availability for the animals, in particular whether it contemplate the needs of the livestock under feedlot conditions.

According to Averós et al. (2014), who studied the effects of space availability on the behavior of gestating dairy ewes, the space is an essential element in the adequacy of livestock facilities, because it severely impacts animal welfare. Many researchers have associated limited space with poor cattle welfare due to mud accumulation (Mader, 2011; Macitelli and Paranhos da Costa, 2015 - previous chapter), restriction in the expression of maintenance behaviors (Fraser, 1983; Fraser et al., 2013), increased frequency of agonistic behavior (Kondo et al., 1989), higher risk of hoof lesions (Salak-Johnson et al., 2007), and decreased immunity (Salak-Johnson et al., 2012) and product quality (Sevi et al., 1999). Furthermore, all these factors can reflect negatively on cattle performance (Wechsler, 2011; Krawczel et al., 2012). For instance, Mader (2011) reported a higher production cost when the space availability is reduced in the beef cattle feedlot, since the weight gain decreases while feed conversion increases. Similar results were found for beef heifers, where physiological and psychological stresses induced by space restriction were suggested to underlie the reduction in animal performance (Fisher et al., 1997). In addition, high density feedlots is increasingly been perceived negatively by the consumers concerned about the welfare of farm animals (Vanhonacker et al., 2009).

Despite the existing knowledge about the relevance of feedlot space for cattle welfare, most of the studies so far were conducted with cattle maintained in small indoor feedlots, usually housing only a few animals at high stock densities (Kondo et al., 1989; Fisher et al., 1997; Gygax et al., 2007; Gupta et al., 2007). However, the combination of available area per animal and group size employed in some of these studies may have confounded the results interpretation. Moreover, these conditions do not foster the consideration of many outdoors environmental effects such as shelter absence with direct, and sometimes excessive, exposition to climatic factors (Gaughan et al., 2010;

laer et al., 2014), and even the social relationships, which differ between large or small groups of animals (Lindberg, 2001; Fraser et al., 2013). To our knowledge, only one study assessed the impact of space allowance in commercial outdoor feedlots on cattle performance (Mader, 2011), but it was performed under different conditions, such as climate, nutrition, confinement period, and breed. Thus, it is necessary to further our understanding on how space allowance can improves the efficiency of commercial outdoors feedlots in tropical regions. This study was carried out to test the hypothesis that the space allowance in commercial outdoor feedlots affects beef cattle performance as well as carcass and meat quality. To do so, we evaluated these parameters in beef cattle maintained in outdoors feedlot with three different space allowances.

Materials and methods

This study was approved by the Ethics Committee on Animal Use, from the FCAV-UNESP (CEUA - protocol number 025961/13).

Local and period of study

The study was conducted in a commercial feedlot in Campo Verde, Mato Grosso State - Brazil (15º32'48" S and 55º10'08" W, 736 meters above the sea level) from August 20 to November 15, 2012, totalizing around 87 days in feedlot.

The black globe temperature (BGT, °C), air temperature (AT, °C) and relative humidity (RH, %) were measured systematically during the study period. BGT was monitored using a black globe and AT and RH using a digital thermo-hygrometer (Incoterm® - model 7663); being recorded at 20-minute intervals between 7 and 17 h every other day in the first two weeks of study and then weekly until the end of the experimental period. Rainfall (mm) was registered systematically using a manual pluviometer. The cumulative amount of rainfall (mm) and the means of the maximum and minimum BGT, AT, and RH per week over the study period are presented in Figure 1 A, B and C, respectively.

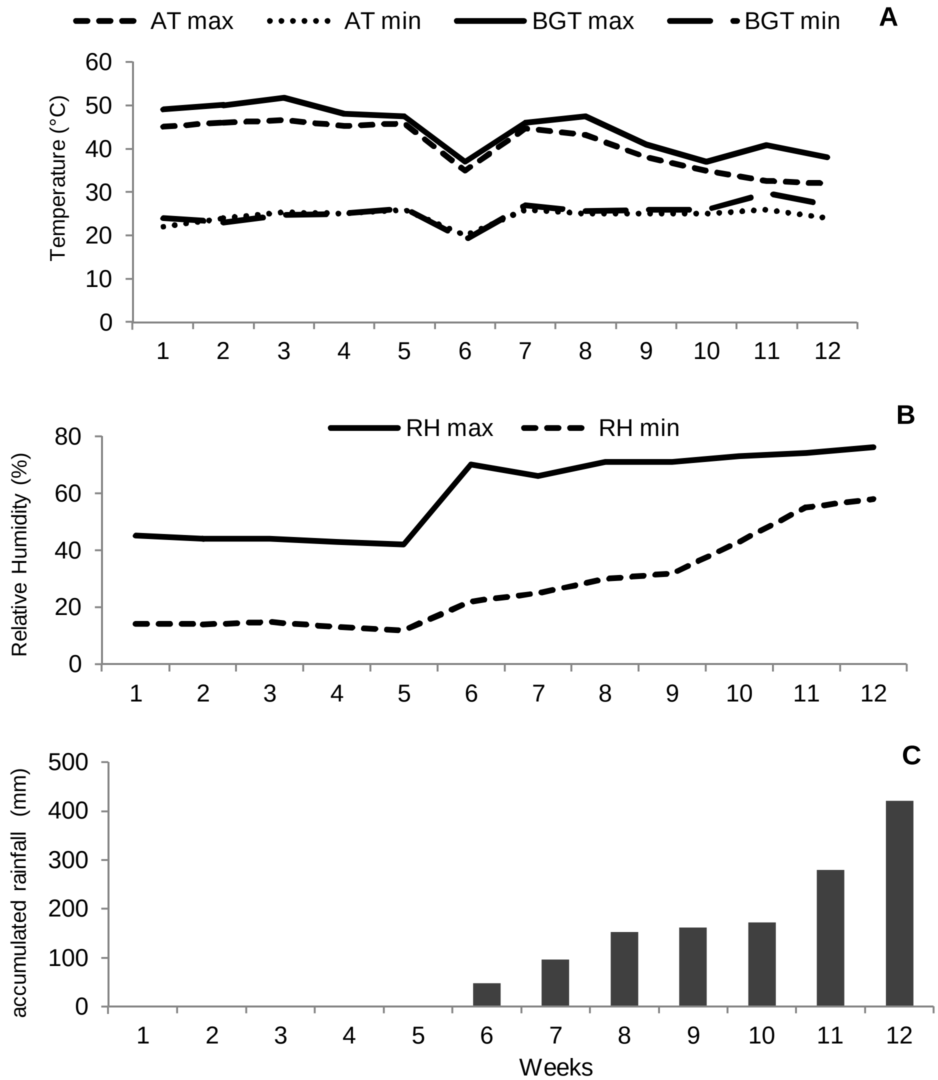

Figure 1. A – Means of the maximum and minimum air temperature (AT) and black globe (BGT) temperatures; B - relative humidity (RH); and C - accumulated amount of rain, per week.

Animals, treatments and facilities

One thousand three hundred and fifty bulls were evaluated, 900 were F1 crossbred Aberdeen Angus or Caracu x Nellore cattle and 450 pure Nellore breed. In the beginning of the feedlot period the animals were around 30 ± 6 months of age and weighing on average 392 ± 46 kg. The animals were individually identified with numbered ear tags.

All animals were transported to the farm two weeks before starting the feedlot operations, and during this period they were kept on pasture (*Brachiaria ruziziensis*) with free access to mineral supplement and water. All animals were weighed, vaccinated (against clostridial diseases) and dewormed (using Doramectin 1%) just before entering in the feedlot facilities, being assigned to nine lots (with 150 animals each). The lots were divided in the three treatments, one with Nellore and two with Crossed cattle, considering the space allowance of 6 (T6), 12 (T12) and 24 (T24) m^2 per animal. The space allowance was defined considering the area commonly used in commercial Brazilian feedlots (12 m^2/animal), besides halving and doubling it.

The layouts of the confinement pens are shown at Figure 2. They were enclosed by fences, and their surfaces had approximately 5% slope. The water and feed trough were made with concrete, the water troughs measured about 1.5 meters of diameter, being common for each two pens and cleaned three times a week; and there were 50 meters feed bunk lines per pen (33 cm per animal). The variation in the pen areas was made changing their length, being 18, 36 and 72 m for T6, T12 and T24, respectively.

Diet and feeding management

Two diets were used during the study period, the "adaptation", offered in the first 25 days of confinement, and the "finishing", offered from the 26th day until the end of the experiment, whose compositions are shown in Table 1. The diets were formulated by RLM® program (a Brazilian nutritional program that consider the age, body weight, sexual condition, genetic group, the nutritional composition and digestibility of the Brazilian foods, and the market value of ingredients, aiming the maximum profit). The average of daily weight gain expected, for the entire feedlot period, was 1.6 kg/animal. The animals were fed four times a day, twice in the morning (07:30h and 10:00h) and in the afternoon (14:30h and 16:30h). Before the first feeding of the day, a previously trained employee evaluated the feed bunks, providing a feed bunk score for each pen, as shown in Table 2. According to the score, it was calculated the amount of food per pen. Generally the animals received 40% of the total amount of food at the last feeding of the day and 20% in each of the other three feedings.

Table 1. Composition of the diets offered to the animals during the study period (% of Dry Matter)

Ingredient	Adaptation	Finishing
Corn silage	44.03	14.00
Cotton hull	0.00	12.50
Corn residue*	7.09	10.20
Milled corn	26.18	40.30
Cotton seed cake	12.67	12.38
Soybean skin	8.13	8.84
Other**	1.90	1.78
Total	100.00	100.00

Estimated dry matter intake = 2.4% of live weight.
Total digestible nutrients (TDN) = 65% for adaptation diet and 72% for finishing diet.
* Residue from corn storage; ** 14.93% mineral salt, 85% urea and 0.074% sodium monensin.

Table 2. Appointed scores to evaluate the feed bunks and define the amount of food offered for each pen per day

Score	Feed bunk condition	Cattle behavior	Amount of food
-2	Empty	Most of the animals (more than 50%) standing in front of the feed bunk	Increase 10% the amount of food in relation to the day before
- 1	Empty	Few animals (less than 25%) standing in front of the feed bunk	Increase 5% the amount of food in relation to the day before
0	Empty or little quantity of food (5 to 10% of the last feeding). It is possible to see the bottom of the feed bunk	Most of the animals is calm and not expecting the food at the feed bunk	Same amount of food than the last day
1	Little quantity of food. It is not possible to see the bottom of the feed bunk (20% of the last feed)	Half of animals standing and half lying down	Decrease 5% of the amount of food in relation to the day before
2	Full	Most of animals lying and ruminating	Decrease 10% of the amount of food in relation to the day before

Adapted from Pritchard and Burns (2003).

Performance traits

Weight gain

The animals were kept in food fasting for 12 hours before weighing. The first weighing (initial body weight, Ibw) was performed when the lots were formed, the second (intermediate body weight, Mbw) 35 days after the animals entry in the feedlot, and the third (final body weight, Fbw) just before loading them into the trucks, to transport for the slaughterhouse.

The following equations were used to estimate the weight gain of each period:

Dwg1 = (Mbw – Ibw) / dp1

Dwg2 = (Fbw – Mbw) / dp2

Dwgt = (Fbw – Ibw) / dpt

Where: Dwg1 = daily weight gain for the first period; Dwg2 = daily weight gain for the second period; Dwgt = daily weight gain for the total period; Ibw = initial body weight; Mbw = intermediate body weight; Fbw = final body weight; dp1 = number of days existent in the first period; dp2 = number of days existent in the second period; dpt = number of days existent in the total period.

The average of the daily weight gains for each period (1, 2 and total) were categorized in order to evaluate the frequency of distribution of the weight gains per treatment, and also to estimate de percentage of animals that was above de expected weight gain (1.6 kg/day).

Carcass weight

Two slaughters were performed in two different commercial slaughterhouses under the Federal Inspection Service (SIF), from the Brazilian Ministry of Agriculture, Livestock and Food Supply, following the guidelines of the Department of Animal Products Inspection (DIPOA, 1997). The first one was on October 26, when one lot of crossbreed bulls of each treatment had reached the body weight that the farm expected, and the second was on November 16, 17 and 19, when the other two lots of each treatment (T6, T12 and T24) were slaughtered.

The slaughterhouse provided the hot carcasses weights (Cw, in kg). According to MAPA (2004), the carcass weight is the weight of the slaughtered animal before cooling, but already bled, skinned and eviscerated, devoid of the head (severed between the occipital bone and atlas), legs (cut at the height of the tarsal-metatarsal joints), oxtail, external genitalia, renal and inguinal fat, spinal cord, diaphragm and its pillars.

Carcass quality traits

Bruises

We considered bruise, as a tissue injury with rupture of the vascular supply and accumulation of blood and serum (Hoffman et al., 1998) developed after the application of force, sufficient to disrupt blood vessels (Bariciak et al., 2003). The ages of the beef cattle carcasses bruises are usually defined according to their colors (Gracey and Collins, 1992), and based on this, it is possible to classify bruises into at least two categories: fresh bruises and bruises that are days or weeks old (Grandin, 2000). The latter would be indicated by the presence of yellow-green color in the damage area, due to macrophages ingestion of red blood cells and metabolization of the hemoglobin to biliverdin and then rapidly to bilirubin (Hughes et al., 2004).

A trained person for visual evaluation assessed the bruises after the skinning, and characterized them according to the age and severity. The new bruises were characterized by red color and the old by yellowish-green color, at least, around the bruise (Grandin, 2000). The severity of the bruise was classified by the tissues affected in the injured area (adapted from INN Chile, 2002), being: ‘Superficial’, when the damaged area comprises only subcutaneous tissues; ‘Muscular’, when the damaged area comprises subcutaneous and muscular tissue and ‘Severe’, when subcutaneous, muscular tissues and even bones are damaged, including fractures.

Fat covering

A trained person observed the distribution and the amount of fat covering the carcasses at 6th, 9th and 12th ribs, dorsal and ventral side of the *Latissimus dorsi* muscle and *Dorsal serratus*, in the lower back and cushion region, and then used the scores proposed by Brasil (2004) to define the fat covering, as follow: 1 - Absent (no visible fat), 2 - Scarce (presence of little visible fat in the aforementioned regions, around 0-3 mm) 3 - Median (reasonable presence of fat covering almost all of the mentioned areas above, about 3 to 6 mm) 4 - Uniform (presence of fat covering all of the above areas, around 6 to 10 mm); 5 - Excessive (presence of excess fat in all the mentioned areas, with more than 10 mm).

Meat quality trait

pH

A slaughterhouse technician measured the meat pH using a digital pHmeter. The measurements were done in the 12th rib region (ribeye), inside of the right half-carcass maintained at temperature about 2°C for 24 hours after the slaughter.

Adrenal glands weight

The right and left adrenal glands of 20% of the animals (randomly selected from each treatment) were collected after slaughter, at the time of evisceration. The glands were dissected (to remove fat and other tissues), identified, placed in plastic bags and refrigerated at 4°C. After 24 hours, they were weighed individually on a precision scale. The Aw was used as a stress indicator.

In order to reduce possible animal carcass weight effect on the adrenal glands weight, it was used in the following equation:

$$Aw = \left((Raw + Law) / Cw\right) * 100$$

Where: Aw = adrenal gland weight; Raw = right adrenal weight, Law = left adrenal weight and Cw = carcass weight.

Statistical Analyses

During the achievement of database consistency, the extreme values were excluded by applying the criterion of average ± 3 standard deviations. The normality was checked for all dependent variables considered continuous (Ibw, Fbw, Dwg1, Dwg2, Dwgt, Cw, pH, adrenal gland weight and medullar and cortical areas) using the Kolmogorov-Smirnov test. The *post-mortem* health indicator was considered as binomial distribution. All data were analyzed using SAS software (SAS Inst. Inc. Cary, NC) and the results were considered statistically different when $P < 0.05$.

To evaluate the effect of treatments (space allowance) in the Ibw, Fbw, Cw, pH, Dwg1, Dwg2, Dwgt and Aw, we applied an analysis of variance by using ANOVA with Proc Mixed. We included, in the statistical model of this analysis, the fixed effect of treatment, and the random effect of genetic groups. However, to analyze Cw and Fbw, the Ibw was included in the model as a covariate, and for Cw and pH, the slaughterhouse was included in the models as a random effect. Means comparisons were performed by post-hoc Tukey test. The effect of treatments on the stress indicator (Aw) was assessed using ANOVA with Proc Mixed.

To assess whether the frequency of fat covering score, Dwg1, Dwg2 and Dwgt depended on the treatments, the chi-square test was applied, using the Proc Freq. The associations between the Aw and all other variables were assessed by estimating the Persons coefficients of correlation, by using the Proc Corr.

The effects of the treatments on the number of new, old and total of bruises per carcass were analyzed applying the Proc Glimmix, considering the fixed effect of treatment, random effect of breed, and data with Poison distribution. Because of the different conditions of transport and slaughter between the two slaughters, we used only the data of bruises collected in the second slaughter, which presented a larger number of animals from each treatment. The effect of treatments on the risk of bruises occurrences was analyzed by logistic regression using the Proc Genmod. The binomial data distribution was assumed with probit link function to an adjacent normal distribution. Ratios of the odds (odds ratios) were calculated to obtain information regarding the possibility of developing bruises between the different space allowances. In this analysis the treatment T24 was assumed as reference category (RC).

Results

Performance traits

The cattle performance was assessed by measuring body and hot carcass weight, and by calculating the daily weight gain (Table 3). No difference among treatments was observed for Ibw ($F_{2, 970}$ = 0.46; P > 0.05), but there were significant differences among treatments for the Fbw ($F_{2, 968}$ = 9.93; P < 0.05), Cw ($F_{2, 968}$ = 2.94; P = 0.05), Dwg1, Dwg2 and Dwgt ($F_{2, 960}$ = 13.64, $F_{2, 959}$ = 64.14, $F_{2, 970}$ = 17.68, $F_{2, 968}$ = 4.19, respectively; P < 0.01). The Dwg1 was lowest for T24 and did not differ between T6 and T12. Interestingly, at longer periods, T24 showed the highest means for Fbw, Dwg2 and Dwgt, followed by T12 and T6. The Cw did not differ between T24 and T12, but both means were greater than the T6 mean.

Table 3. Effect of different space allowances on feedlot beef cattle performance

	Treatment		
Variable	T6	T12	T24
Ibw (kg)	389.16 ± 9.37	390.11 ± 9.34	386,74 ±9.36
Fbw (kg)	526.76 ± 10.12^c	535.45 ± 9.96^b	538.22 ± 10.10^a
Cw (kg)	291.85 ± 1.29^a	294.42 ± 1.23^b	295.17 ± 1.25^b
Dwg1 (kg/d)	2.19 ± 0.08^a	2.14 ± 0.08^a	1.91 ± 0.08^b
Dwg2 (kg/d)	1.30 ± 0.12^c	1.40 ± 0.12^b	1.71 ± 0.12^a
Dwgt (kg/d)	1.60 ± 0.08^c	1.69 ± 0.08^b	1.77 ± 0.08^a

Data are expressed as means (±standard error). Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24). Initial body weight (Ibw), carcass weight (Cw), daily weight gain for the first period (Dwg1- D0 to D35), daily weight gain for the second period (Dwg2 - D36 until the end), and daily weight gain for the total experimental period (Dwgt). Means followed by different letters in the lines are statistically different (Tukey test, P > 0.05).

The percentages of animals for each category of weight gain also differed significantly (P < 0.01) among treatments for Dwg1 (DF = 78, χ^2 = 148.81), DWg2 (DF = 58, χ^2 = 153.76) and DWgt (DF = 42, χ^2 = 106.63,), as shown in the Figure 2 (A, B, and C, respectively). The percentages of animals classified in the daily weight gain average class above 1.6 kg/day were 50, 61.5 e 67.1%, for T6, T12 and T24, respectively.

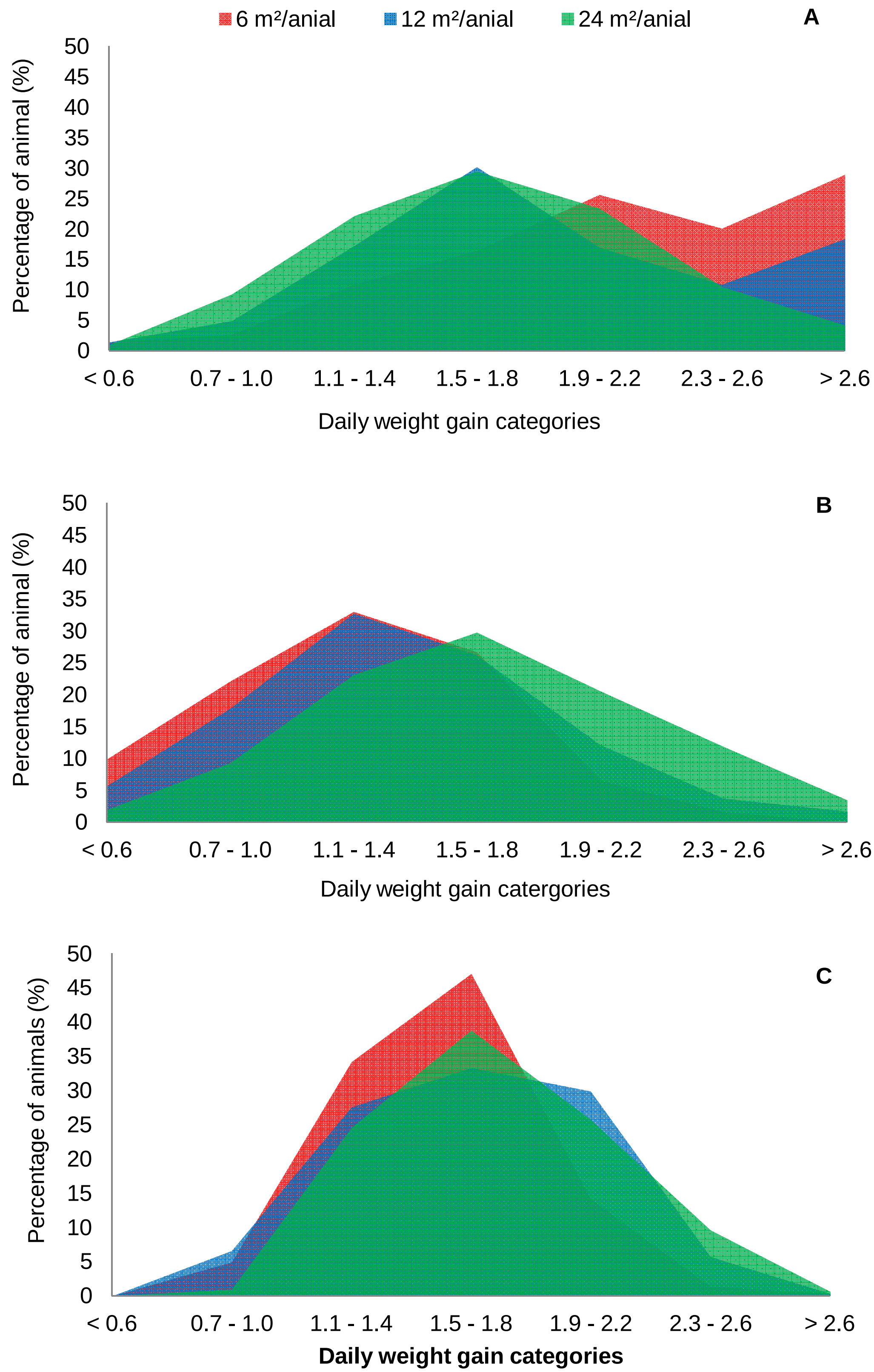

Figure 2. Percentages of animals according to the daily weight gain categories for the first (A), second (B) and total period (C).

Carcass quality

The percentages of cattle for each score of fat covering were also significant different among treatments (DF = 4, χ^2 = 12.89, P = 0.01), as shown in the Figure 3. No carcass performed the scores 4 and 5 for fat covering.

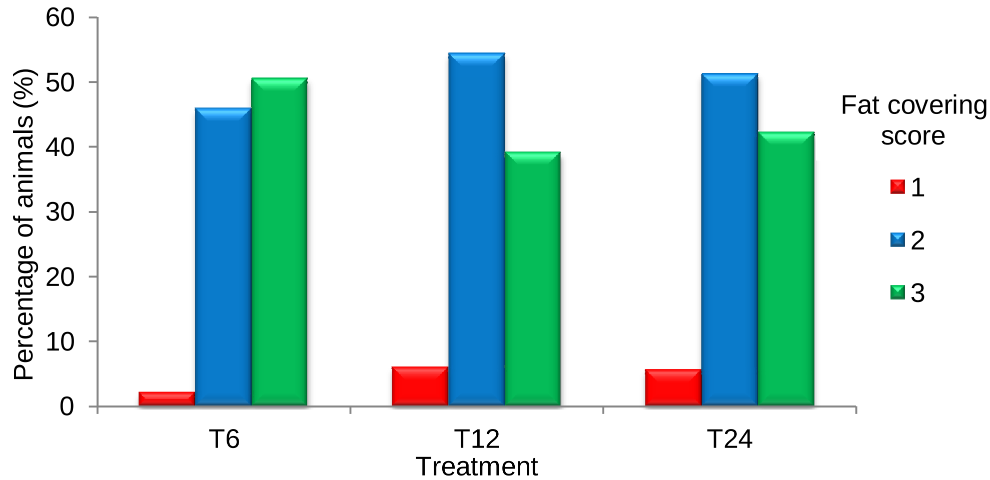

Figure 3. Percentages of animals for each fat covering score according to the treatments. Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24). Fat covering scores ranged from 1 to 5, 1 being the lowest coverage and 5 the highest.

The number of new (P < 0.01; $F_{2, 737}$ = 11.99), old (P < 0.01; $F_{2, 738}$ = 8.55) and total bruises per carcass (P < 0.01; $F_{2, 737}$ = 14.58) differed among treatments. The mean number of new bruises per carcass was lowest for the T24, but did not differ between the T6 and T12. The mean number of old and total bruises per carcass were highest for T12, but T24 and T6 did not differ from each other (Table 4).

The odds ratios of new and total bruises differed among treatments (P < 0.01), as shown in Table 5. We observed an increased risk of occurrence of new and total bruises for T6 and T12. However, the risk of occurrence of old bruises did not differed among treatments.

Table 4. Effect of different space allowances on carcass quality assessed by number of new, old and total bruises per carcass

	Treatment		
Bruise	T6	T12	T24
New	-0.38 ± 0.17[a] (0.50)	-0.20 ± 0.16[a] (0.60)	-0.91 ± 0.18[b] (0.30)
Old	-2.10 ± 0.18[b] (0.12)	-1.23 ± 0.11[a] (0.29)	-1.58 ± 0.14[b] (0.20)
Total	-0.14 ± 0.15[b] (0.62)	0.22 ± 0.14[a] (0.90)	-0.36 ± 0.15[b] (0.51)

Data are presented as adjusted means ± standard error. Observed means are between brackets. Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24). Means followed by the same letters in the lines did not differ statistically (Tukey test, P > 0.05).

Table 5. Odds ratios and respective confidence intervals of bruises occurrences per space allowance

Bruise category per treatment	N	%	Odds ratio	Confidence interval	$\chi 2$
New Bruises					
T6	246	49.59	1.68	1.13 – 2.46	6.72*
T12	266	60.53	1.77	1.20 – 2.64	8.02*
T24	229	30.00	1.00	RC	.
Old Bruises					
T6	246	12.19	0.68	0.41 – 1.17	1.92
T12	266	29.32	1.51	0.95 – 2.41	3.05
T24	229	20.00	1.00	RC	.
Total Bruises					
T6	246	61.78	1.40	0.92 – 2.03	3.23*
T12	266	89.85	1.72	1.20 – 2.46	8.52*
T24	229	50.00	1.00	RC	.

χ^2 test, all P > 0.05. N = total number of evaluated animals; (%) = percentage of animals with bruises, and RC = reference class. Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24).

The number of superficial (P < 0.01; $F_{2,\ 737}$ = 20.13) and muscular bruises (P = 0.01; $F_{2,\ 737}$ = 4.32) differed between treatments. However, it was not possible to analyze the number of severe bruises, since its occurrence was rare, only one animal in T12. According to Table 6, the mean number of superficial bruises per carcass was lowest for the T24 (N = 0.25), followed by T06 (N = 0.48) and T12 (N = 0.65). The mean number of muscular bruises per carcass was lowest for T6 (N = 0.14), with T24 and T12 not differing from each other (N = 0.25 and 0.23, respectively).

Table 6. Effect of different space allowances on carcass quality assessed by severity of bruises per carcass

Bruise	Treatment		
	T6	T12	T24
Superficial	-0.10 ± 0.18[b] (0.48)	0.17 ± 0.16[a] (0.65)	-0.79 ± 0.19[c] (0.25)
Muscular	-2.00 ± 0.19[b] (0.14)	-1.48 ± 0.15[a] (0.23)	-1.40 ± 0.15[a] (0.25)

Data are presented as adjusted means ± standard error. Observed means are between brackets. Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24). Means followed by the same letters in the lines did not differ statistically (Tukey test, P > 0.05).

The odds ratios of superficial and muscular bruises differed between treatments (P < 0.01), as shown in Table 7. There was a pronounced increase in the risk of occurrence of superficial for T6 and T12 compared to T 24 (reference class). However, the risk of muscular bruises occurrence was lower to T6.

Table 7. Odds ratios and respective confidence intervals of bruises severity per treatment

Bruise category per treatments	N	%	Odds ratio	Confidence interval	$\chi 2$
Superficial					
T6	381	37.00	2.37	1.55 – 3.60	15.99*****
T12	403	35.70	2.72	1.13 – 2.46	23.48*****
T24	399	24.89	1.00	RC	.
Muscular					
T6	381	10.97	0.50	0.30 – 0.83	7.27*
T12	403	21.43	0.81	0.51 – 1.27	0.84
T24	399	15.28	1.00	RC	.

χ^2 test, all P > 0.05. N = total number of evaluated animals; (%) = percentage of animals with bruises, and RC = reference class. Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24).

Meat quality

There were differences among treatments for meat pH ($F_{2, 960}$ = 5.40; P < 0.01). The highest mean value was observed for the T6 (5.63 ± 0.03; P < 0.05) followed by T12 and T24 (5.61 ± 0.03 and 5.60 ± 0.04, respectively), which did not differ between each other (P > 0.05).

<u>Association of adrenal weight with performance and meat quality traits</u>

The adrenal glands weights differed among treatments ($F_{2, 25.49} = 9.95$; $P < 0.01$). The T24 displayed the lowest mean (8.22 ± 1.20 g/100 kg Cw), while T6 and T12 means did not differ from each other (8.87 ± 1.13 and 8.77 ± 1.12 g/100 kg Cw, respectively). Significant correlations were observed between the adrenal glands weight and some performance and carcass and meat quality variables, as show in Table 8.

Table 8. Associations between the adrenal gland weight and performance, carcass and meat traits

		Treatment		
Variable	All treatments	T6	T12	T24
Dwg1	0.04	-0.11	-0.16	0.07
Dwg2	-0.20**	-0.15	-0.29*	-0.03
Dwgt	-0.10	-0.17*	-0.30**	0.02
Cw (kg)	-0.30**	-0.42**	-0.37**	-0.31**
pH	-0.07	-0.01	0.10	0.19
Fat covering	-0.02	-0.02	-0.30**	0.01
New Bruises (n°)	0.05	0.22†	-0.04	-0.11
Old bruises (n°)	0.10	0.21†	-0.01	0.06
Total bruises (n°)	0.11	0.29**	-0.04	-0.05
Superficial bruises (n°)	0.13†	0.15	0.02	0.01
Muscular bruises (n°)	0.00	0.28**	-0.08	-0.09
Severe bruises (n°)	-0.04	-	-0.11	-

Treatments considered the space allowance per animal in the feedlot pens, being 6 m² (T6), 12 m² (T12) and 24 m² (T24). n° = number. Person correlations coefficient between adrenal weight and the variables: daily weight gain for the first period (Dwg1- D0 to D35), daily weight gain for the second period (Dwg2 - D36 until the slaughter), observed daily weight gain for the total experimental period (Dwgt), carcass weight (Cw). *P < 0.05; **P < 0.01; †P = 0.06.

Discussion

There is a strong tendency to reduce the space in beef cattle feedlots, and this is mainly justified by the possible profit benefits achieved by production per area increment. However, such initiative usually ignores the animals' needs and the environmental impact, affecting animal welfare and raises worrisome ethical issues. For this reason, we evaluated the effect of feedlot space allowance on cattle performance, and carcass and meat quality, by halving and doubling the area commonly used in commercial Brazilian feedlots. We found that the animal performance and carcass quality were directly affected by the space allowance.

Performance traits

Weight gain is an indicator commonly used to evaluate animal performance, and can be affected by feed ratio, breeding, management (Herva et al., 2009) and space allowance (Fisher et al., 1997; Gygax et al., 2007). The means of Dgw1 suggested that space availability during the first 35 days in feedlot is not a limiting resource for weight gain, because the daily gains of T6 and T12 animals were in average 12.24% greater than T24. However, in the second period (after 36th day until the slaughter) all treatments showed decreased daily weight gain, and this reduction was inversely proportional to the space availability, decreasing 40.6%, 34.6%, and 10.5% for T6, T12 and T24, respectively.

It is expected a weight gain reduction after the first month in feedlot, and is probably due to a decreased efficiency of energy utilization by the difference of animals' physiological stage (Church, 1993; Van Soest, 1994). Moreover, it is possible that the high rainfall observed during the second period (Figure 1C) may have contributed to results obtained. Indeed, high rainfall increases mud accumulation (Macitelli and Paranhos da Costa, 2015 – previous chapter) and, if animals are kept in high density, they diminish their food consumption and hence reduce their performance (Mader, 2011). Mud accumulation tend to decrease in higher space allowance because of the possibility of the presence of dry areas (Mader, 2011), which may help explain the observed inverse correlation between space availability and weight gain reduction. Moreover, reduction of space allowance was related to health and behavior problems, affecting indirectly the cattle performance (Andersen et al., 1997; Gygax et al., 2007; Macitelli and Paranhos da Costa, 2015 – previous chapter). Considering all the experimental period, the T24 displayed a Dwgt approximately 11.8% higher than the other treatments. Although weight gain is widely used as a performance indicator, it is relevant to emphasize that the distribution of weight gain for each treatment is also an important performance indicator, mainly because with this information we would be able to compare the homogeneity of the lots and shows the percentages of animals which are at the extremes of the curves. As shown in Figure 2A, the distribution of animal weight gain during the first 35 days of confinement is quite irregular and wide (with animals gaining between 0.0 and 3.8 kg/day), with T6 showing greater percentage of animals gaining more than 2.0 kg/day, followed by T12 and T24, as seen in Table 3. However, during the most challenging period (52 days, and with the change of the dry period to the rainy one – Figure 1C), it is possible to observe more uniform weight gain distribution curves, and remarkable superiority of T24, followed by T12 and T6 (Table 2B), which is repeated in the Dwgt figure (Figure 2C).

Taken together, these data indicate that space allowance is a relevant resource for the weight gain of cattle confined outdoor, a fact well established for indoors feedlot (Fisher et al., 1997; Gygax et al. 2007; Gupta et al., 2007).

Carcass and meat quality traits

The fat covering of carcass is indirectly associated to the meat quality because it controls the speed of temperature drop and the action of enzymes that transform glycogen into lactic acid, which lowers meat pH (McGilchrist et al., 2012). Despite of the significant differences among the treatments found for pH and fat covering, all the results were within the acceptable range for a good carcass quality (MAPA, 1952; EUR-lex, 2007).

Several factors affect the deposition of fat in cattle carcasses, with the energy source and concentration in the diet considered the most important, especially at the fattening period (Petty and Cecava, 1995; Drackley et al., 2014). Because all treatments received the same diet, other factors than energy concentration should account for differences in carcass fat deposition observed among treatments. Interestingly, despite T6 showed the lowest weight gain, the animals from this treatment displayed the highest frequency of fat covering score 3. We suggest that the stress caused by the space restriction altered the energy metabolism of the animals. Indeed, several cattle studies have showed that animals kept under space limitation displayed higher glucocorticoids levels (Friend et al., 1979; Gupta et al., 2007), which is partially responsible for the observed changes in the metabolism and distribution of adipose tissue (Rebuffe-Scrieve et al., 1992; Peckett et al., 2011).

A well and standardized fat coverage is desired by slaughterhouses, however, the fat coverage depends on many other factors such as diet and genetics, besides being affected by metabolic disorders caused by stress. As already reported (Finger et al., 2012; Lee et al., 2014), chronic stress conditions increases the adipocytes cells, mainly the visceral fat deposition, what points a lower efficiency of diet utilization by the animal to deposit tissues that really are profitable. To our knowledge, there are no results about how chronic stress may increase the fat accumulation in beef cattle adipocytes cells. These studies were conducted commonly in rats and human, because the direct relationship between abdominal fat with metabolic and cardiovascular diseases in humans (Finger et al., 2012; Lee et al., 2014). It would be important to conduct further studies addressing the association between variables indicators of chronic stress and the variables that indicate visceral and covering fat deposition and metabolic diseases in cattle.

Another variable used to assess the carcass quality, was the bruises occurrence. Our initial hypotheses was that T6 would show highest number of bruises, mainly the old and the muscular ones, because it is known that space restriction may increases the physical contact and agonistics behaviors (Lindberg, 2001; Rodenburg and Koene, 2007), and as reported also by Kondo et al. (1989), who observed significant negative correlation between space and agonistic behaviors to feedlot cattle ($r^2 = -0.48$; $P < 0.01$). However, we observed that animals from T6 and 12 reduced their locomotion over the time, as well as T6 showed higher percentage of animals with hooves alteration (three times higher than T12 and twice than T24), greater mud depth and increased incidence of diseases (Macitelli and Paranhos da Costa, 2015 - previous chapter). Thereby, we suppose that animals from T6 could be physically exhausted, thus decreased their agonistics interactions, reducing the number of old (bruises with more than 24 – 48 hours, developed in the farm) and muscular bruises. In contrast, animals with more space allowance (T24) would be able to maintain the frequency of agonistic interactions, but also would be able to escape, preventing them. The animals from T12 apparently are in a situation between T6 and T24, where the space did not allowed them to avoid agonistic encounters, and moreover the animals were in better physical condition than T6. Then, one could suppose that the lower number of new and superficial bruises exhibited by the animals from T24 were associated to their apparent tranquility. Nevertheless, we highlight that other factors, not strictly controlled in this study, are very relevant for the new bruises occurrence and also their severity, such as poor pre-slaughter handling, transport and facilities design, and the cattle temperament (Strappini et al., 2010; Paranhos da Costa et al., 2012; Shwartzkopf-Genswein et al., 2012). These authors also recognize that the number and severity of bruises on cattle carcass is an important aspect used to assess animal welfare, and may provide information about the damaging, stressful and potentially painful situations that the animal experienced previously to slaughter (Strapinni et al., 2009; Basbaum and Woolf, 1999; Gregory, 2007).

According to Grandin (2000), bruises are cause of economic losses, since the severe bruises should be removed from carcasses, disfiguring the meat cuts, and by this affecting the producers and industries profitability. The muscular bruises occurrences were higher for T12 and T24 than for T6, and this fact can be the responsible for these treatments do not have higher carcass weight than those shown.

It must be emphasized that the decreased meat quality are directly dependent of the bruises presence and meat pH (Strappini, 2009). Moreover, bruised meat decomposes quickly, because it is a perfect condition for microorganisms growth (FAO, 2001), leading to a shorter shelf-life and not a good taste.

Association of adrenal weight with performance and meat quality traits

Under chronic stress situations, such as space limitation, the HPA axis stimulates the adrenal cortex to release higher levels of glucocorticoids, such as cortisol, into the blood (Carroll and Forsberg, 2007; Jensen, 2014). The adrenal over stimulation have a catabolic effect on tissues, since an excess of glucocorticoids is able to inhibit several body activities and negatively influences cellular proliferation and differentiation (Rosmond and Björntorp, 2000). Accordingly, the adrenal gland weight can be used as a stress indicator by the hypertrophy and hyperplasia caused by chronic stress (Shively and Kaplan, 1984; Ulrich-Lay et al., 2006; Harvey, 2014).

Thereby, we observed that the adrenal gland weight was lowest for T24 and associated only with Cw. However, highest adrenal gland weights were considerably associated with Dwgt, Cw, total number of bruises and muscular bruises occurrence for T6, and Dwg2, Dwgt, Cw and carcass fat covering for T12. These results suggest that animals from T6 and T12 were subjected to a more stressful environment, which increased the activity of the adrenal glands and consequently affect important variables used to assess the performance and carcass and meat quality. The endocrine profile observed in stressed animals is associated to many productive-hormones, which strongly influence the immunocompetence and have a significant impact on nutritional status of the animals (Carroll and Forsberg, 2007). Indeed, results obtained by Montanholi et al. (2013) reinforces that positive association between improved feed efficiency and fecal cortisol metabolites levels over the finishing phase of feedlot cattle.

Conclusions

The animals under 24 m^2/animal displayed better performance results; however, it is possible that higher space allowance (more than 24 m^2/animal) could be better, improving even more the environmental conditions, animal welfare and cattle performance, mainly during rainy periods. Thus, it is precipitate to recommend 24 m^2/animal as the optimum space allowance by using only the results found in this study. We conclude that the space availability is relevant for outdoors feedlot cattle, and its reduction can affect negatively the animal welfare and performance.

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CAPÍTULO 4 - Considerações finais

Implicações gerais

A tendência de redução de espaço nos confinamentos brasileiros, em função principalmente da busca pelo aumento da receita por área (com expectativa de obtenção de maior lucro) é uma realidade, mas sua adoção deve ser realizada com cautela, pois há riscos de efeitos colaterais negativos para o bem-estar e desempenho dos bovinos confinados.

O maior acúmulo de lama e concentração de poeira em função da redução da disponibilidade de espaço para os bovinos são indicadores de potenciais problemas de saúde aos animais. Salientamos que as pessoas envolvidas no manejo diário do confinamento também podem desenvolver doenças, principalmente respiratórias, devido a maior exposição a agentes patogênicos e tóxicos presentes na poeira e lama.

É comum observar que os confinamentos realizam vistoria diária aos currais focando principalmente o manejo alimentar, avaliando a disponibilidade de alimento no cocho, bem como o número de animais se alimentando e deitados, e a consistência das fezes apresentada pelos mesmos. Além disso, esta vistoria contempla a observação de bovinos que expressam sinais clínicos evidentes de doenças e lesões graves. No entanto, geralmente os sinais clínicos sutis não são percebidos, apesar de muitas vezes estarem associados com doenças que resultam na redução do desempenho dos animais.

Amparado nos resultados obtidos, a redução da disponibilidade de espaço foi diretamente associada à incidência de tosse, de espirros e à presença de animais com corrimento nasal e ocular. De fato, essas observações podem ser confirmadas por achados macroscópicos *post-mortem* de doenças respiratórias, em especial à pneumonia. Portanto, as vistorias diárias devem compreender não somente a observação de um único indicador de bem estar que é a nutrição, mas o uso simultâneo de visualização de sinais clínicos de doenças e de dificuldades de locomoção dos animais, que devem ser incluídos nas vistorias para que se tenha uma avaliação mais segura do estado de bem-estar dos animais em um dado momento.

Deve-se destacar que a mudança da atitude do trabalhador pode ter grande relevância para o bom funcionamento do sistema. Com observações atentas, podem-se detectar falhas no sistema de produção, que irão nortear a busca de soluções para os problemas, que devem ser simples e viáveis. Ressaltamos que ao conhecer o comportamento dos bovinos, permite-se melhor interação entre o homem e os animais, como também um manejo personalizado, sendo, portanto respeitados os seus limites e o seu tempo de desempenho individual.

O aumento de disponibilidade de espaço pode ser um elemento fundamental para a redução do estresse dos bovinos confinados, pois permite aos animais maior disponibilidade de locais mais secos para se deitarem, além de oferecer condições para que haja redução nas interações agonísticas entre os animais. Outros benefícios desta adoção seriam o menor contato dos animais com agentes patogênicos, manutenção do corpo mais limpo e menor risco de acidentes. Nesse contexto, disponibilizar mais espaço aos bovinos confinados é uma forma de fornecer um ambiente que contempla a possibilidade dos animais apresentarem alguns de seus comportamentos de manutenção individual, como por exemplo, a locomoção, descanso, exploração e cuidados corporais.

O aumento da disponibilidade de espaço em um confinamento, proposto neste trabalho, poderá ser implantado em fazendas sem altos custos, desde que tenham áreas livres para tal ampliação, sendo esta mudança baseada no reposicionamento e ampliação das cercas dos currais, delimitando o novo espaço. Para tanto, se faz necessário um estudo *a priori* das particularidades de cada fazenda.

Os resultados encontrados nesse estudo indicam claramente que a tendência dos confinamentos em reduzir a disponibilidade de espaço para menos de 12 m²/animal não é recomendável. Ainda ressaltamos a necessidade de se repensar o uso de 12 m²/animal, já que o melhor desempenho dos animais mantidos em currais com maior disponibilidade de espaço pode ser uma característica indicadora de que o ambiente é menos estressante.

Não recomendamos o uso de disponibilidade de espaço com o número absoluto de 24 m²/animal, afinal esse é o primeiro estudo com esse tema em condições brasileiras e muitas características específicas de cada fazenda devem ser consideradas, podendo esse valor ser maior ou não. No entanto nossos resultados são capazes de alertar as pessoas que trabalham, direta e indiretamente, com confinamento, de que mais espaço é fundamental aos bovinos confinados.

Destaca-se ainda que este estudo foi realizado num contexto comercial, usando o tamanho de grupo, manejo diário e ambiente de um autêntico confinamento de bovinos em condições tropicais, o que aumenta a validade dos resultados.

Avaliação econômica

Para ajustar a disponibilidade de espaço de 12 m² para 24 m²/animal nos três currais destinados ao desenvolvimento desse estudo, estimou-se o custo a partir dos seguintes materiais utilizados:

- 750 metros de arame x R$ 420,00/km = R$ 315,00
- 48 lascas de madeira x R$ 270,00/dúzia = R$ 1080,00
- 6 diárias x R$ 80,00/diária = R$ 480,00
- outros = R$ 200,00

Total = R$ 2075,00 / 3 currais = R$ 691,67/curral ou R$ 4,61/animal

Comparação entre 12 e 24 m²/animal – diferença de ganho de peso diário de 80g /dia:

150 animais/curral x 0,08kg/dia * 87 dias = 1.044 kg

1.044 kg x 70% de rendimento de ganho de peso* = 730,8 kg = 48,72@

48,72@ x R$ 100,00** = R$ 4842,00 de ganho por curral ou R$ 32,28/animal

Receita – Custo

R$ 32,28 - R$ 4,61 = R$ 27,67 de lucro por animal

* O valor do rendimento de ganho de peso utilizado na fórmula é o encontrado comumente na literatura. ** Valor da arroba no estado de Mato Grosso na época do desenvolvimento do estudo.

A partir dessa simulação, podemos concluir que o custo para a ampliação dos currais pode ser próximo de R$ 30,00/animal que o investimento ainda será pago em um único ciclo do confinamento (lembrando que esses ganhos de peso foram obtidos no segundo ciclo do confinamento, ou seja, agosto a novembro). Considerando o valor da diferença do ganho de peso entre 6 e 24 m²/animal (170 g/dia), o lucro é maior que o dobro do apresentado.

Perspectivas futuras

É inquestionável que a intensificação da bovinocultura é uma tendência em todo o mundo, e que o desenvolvimento de manejos que assegurem menor estresse melhoram o bem-estar dos animais e consequentemente podem maximizar a expressão do potencial produtivo dos mesmos. São escassos os resultados de pesquisas onde o bem-estar animal é considerado um fator relevante na produção de bovinos de corte, portanto, acreditamos serem necessários estudos nessa área, que auxiliem os produtores a melhorar o ambiente e o manejo dos animais.

O Brasil é um país que apresenta diferentes climas, raças e instalações, portanto, o emprego dos dados apresentados nesse estudo merece cautela, afinal podem apresentar-se diferentes em outras condições ambientais.

Acreditamos ser necessário o incremento da produção e da rentabilidade da pecuária, mas não sob a imposição dos animais a situações nas quais eles continuam produzindo, mas desenvolvendo doenças, sentindo dor, ameaça e medo. A ética é a base de uma pecuária sustentável e desenvolvida, e segundo o filósofo Peter Singer, ela requer evitar o sofrimento ao máximo dos seres humanos e dos animais, afirmando que devemos fazer o bem aos seres vivos simplesmente porque isso é bom.