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Rita de Albernaz Gonçalves da Silva

Pigs are ok, why change? Voices of pig production stakeholders in relation to animal welfare and antibiotics use

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Orientadora: Profa. Maria José Hötzel, Dra.
Co-orientadora: Gabriela Olmos Antillón, Dra.

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O presente trabalho em nível de doutorado foi avaliado e aprovado por banca examinadora composta pelos seguintes membros:

Profa. Patrizia Bricarello, Dra.
Universidade Federal de Santa Catarina - UFSC

Dayane Lemos Teixeira, Dra.
Institute of Agrifood Research and Technology – IRTA

Profa. Rosangela Poletto, Dra.
Instituto Federal do Rio Grande do Sul –IFRS
Campus Sertão

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Profa. Maria José Hötzel, Dr.
Orientadora

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RESUMO

Os sistemas de criação intensiva de suínos são fontes de estresse relacionadas com a redução do bem-estar animal e levam ao uso abusivo de antimicrobianos. Evidências científicas associam o uso de antibióticos (AMU) na pecuária intensiva como fator de risco para disseminação de resistência antimicrobiana (AMR) à população humana. O objetivo desta tese foi explorar os conhecimentos e atitudes dos atores da cadeia produtiva de suínos sobre bem-estar animal sobre AMU e AMR. No primeiro capítulo realizamos 58 entrevistas com suinocultores a fim de caracterizar AMU nas granjas de suínos e explorar as atitudes dos produtores sobre cenários restritivos de antibióticos e AMR. Os resultados deste estudo mostraram uma dependência dos antibióticos como ferramentas de prevenção de doenças, em detrimento da adoção de medidas de biossegurança. Identificamos práticas inapropriadas de AMU, como alto uso de antibióticos de amplo espectro e dosagem ou duração do tratamento incorretas, além de acesso irrestrito a antibióticos. Contudo, a maioria dos produtores considerou este AMU legítimo para garantir a produtividade do rebanho e mostrou despreparo e resistência à mudança em suas práticas, percebendo limitações (econômicas, sanitárias e fiscalizadoras) mais facilmente do que alternativas para reduzir o AMU. No segundo capítulo analisamos 44 entrevistas com os mesmos suinocultores, abordando o bem-estar dos suínos e sua relação com a AMU. Identificamos muitos indicadores de manejo e baixo bem-estar animal, como práticas de manejo dolorosas e estressantes e ambientes que limitam a expressão de comportamentos naturais. No entanto, a maioria dos entrevistados estava satisfeita com os padrões de bem-estar animal em suas propriedades. Embora tenham identificado todas as dimensões que impactam o bem-estar de um suíno na granja (funcionamento biológico, estado emocional e naturalidade), sua realidade social, demandas da indústria e assessoria técnica disponíveis os levaram a perceber seu âmbito de ação limitado aos aspectos biológicos e ambientais que não necessariamente beneficiam o estado afetivo da animais. No terceiro capítulo exploramos os conhecimentos e as atitudes de 32 profissionais da cadeia produtiva animal sobre a AMU, AMR e sua relação com o bem-estar animal. Embora a maioria dos profissionais acreditava que a AMU era inadequada em fazendas de suínos, suas atitudes foram majoritariamente negativas para um cenário restritivo de AMU. Os antibióticos foram descritos como um recurso preventivo aceitável frente às condições insatisfatórias de manejo e biosseguridade das granjas e essencial para a produção de alimentos baratos. O mercado externo foi considerado um fator de mudança mais relevante na AMU do que os riscos da AMR para as pessoas ou a pressão dos consumidores brasileiros, visto que a AMR foi mais associada ao uso inadequado de antibióticos saúde humana. De forma geral os resultados dos três estudos evidenciam uma estrutura alicerçada com base nos antibióticos, com pilares sociais, econômicos e sanitários. Identificamos relações de emprego e renda no AMU que levam a baixa motivação ou autonomia para mudanças de comportamento em relação a AMU em suínos. A visão limitada de que o bem-estar animal faz parte de um pacote tecnológico foi compartilhada entre os grupos participantes de todos os estudos. Acreditamos que a responsabilidade pelo uso racional de antibióticos é coletiva e requer políticas coletivas multidisciplinares, definidas de forma clara e uníssona e que conduzam a ações concretas de combate à AMR no Brasil.

Palavras-chave: AMU, AMR, suínos, bem-estar animal, antibióticos

ABSTRACT

Intensive pig rearing systems are a source of stress related to the reduction of animal welfare and the abusive use of antibiotics. Scientific evidence associates the use of antibiotics (AMU) in intensive livestock farming as a risk factor for the spread of antibiotics resistance (AMR) to the human population. The aim of this thesis was to explore the knowledge and attitudes of social actors in the pig production chain about animal welfare on AMU and AMR. In the first chapter we conducted 58 interviews with pig farmers in order to characterize AMU on pig farms and explore producers' attitudes about restrictive AMU scenarios and AMR. The results of this study showed a dependence on antibiotics as disease prevention tools, to the detriment of the adoption of biosecurity measures. We identified inappropriate AMU practices, such as high use of broad-spectrum antibiotics and incorrect dosage or duration of treatment, and unrestricted access to antibiotics. However, most farmers considered this AMU legitimate to ensure the productivity of the herd and showed unpreparedness and resistance to change in their practices, perceiving limitations (economic, sanitary and inspection) more easily than alternatives to reduce AMU. In the second chapter we analysed 44 interviews with the same pig farmers, addressing the welfare of pigs and their relationship with AMU. We identified many indicators of management and poor animal welfare, such as painful and stressful management practices and environments that limit the expression of natural behaviours. However, most farmers were satisfied with the animal welfare standards on their farmers. Although they identified all the dimensions that impact the wefare of a pig on the farm (biological functioning, emotional state and naturalness), their social reality, industry demands and available technical advice led them to perceive their scope of action limited to biological and environmental aspects that do not necessarily benefit the affective state of the animals. In the third chapter, we explored the knowledge and attitudes of 32 professionals in the animal production chain about the AMU, AMR, and their relationship with pig welfare. Although most professionals believed that AMU was inadequate on pig farms, their attitudes were mostly negative towards a restrictive AMU scenario. Antibiotics were described as an acceptable preventive tool in the face of unsatisfactory management and biosecurity conditions on farms and essential to produce cheap food. The external market was considered a more relevant driver of change in AMU than the risks of AMR for people or the pressure of Brazilian consumers, as AMR was more associated with the inappropriate use of antibiotics in human health. In general, the results of the three studies show a structure based on antibiotics, with social, economic and health pillars. We identified employment and income relationships in the AMU that lead to low motivation or autonomy to change behaviour in relation to AMU in pigs. The limited view that animal welfare is part of a technology package was shared among groups participating in all studies. We believe that the responsibility for prudent AMU is collective and requires multidisciplinary policies, defined in a clear and unified manner and that lead to concrete actions to combat AMR in Brazil.

Keywords: AMU, AMR, swine, animal welfare, antibiotics

RESUMO EXPANDIDO

Introdução

A resistência bacteriana a antibióticos (AMR) é uma emergência potencial de saúde pública do século XXI. Reconhecendo esse problema, os principais órgãos de saúde mundiais definiram o Plano de Ação Global (FAO, 2016; WHO, 2015) que busca nortear o combate a AMR através do uso prudente de antibióticos na medicina humana e veterinária. A inciativa One Health é uma abordagem única de saúde que relaciona saúde humana, animal e ambiental como partes de um sistema único interconectado e interdependente (SEIFMAN; KATZ, 2016) Essa iniciativa conjunta preconiza dentre outros cuidados resguardar princípios ativos de antibióticos criticamente importantes para humanos (WHO, 2019), restringir princípios ativos (MAGNUSSON et al., 2019).

Os antibióticos são ferramentas muito utilizadas na criação animal e em especial na suinocultura. A criação intensiva de suínos usa antibióticos como promotores de crescimento, como preventivos de enfermidades em momentos estressantes e como terapêuticos no controle de infecções (BOKMA et al., 2014). Os rebanhos de suínos e aves são os que mais utilizam antibióticos comparativamente a criação de bovinos e outros animais (VAN BOECKEL et al., 2015). O alto uso de antibióticos está associado com condições precárias de biosseguridade, tais como medidas de higiene e desinfecção das instalações e das pessoas, e de bem-estar às quais os suínos estão submetidos durante sua vida. Suínos criados em sistemas intensivos, mantidos em alojamentos com limitações exploratórias e submetidos a manejos dolorosos e aversivos estão em estresse crônico. O estresse crônico aliado a uma suscetibilidade intrínseca dos animais de alto desempenho torna os suínos vulneráveis aos patógenos ambientais, e isso se reflete em um maior uso de antibióticos nos rebanhos. Melhorar a qualidade de vida dos suínos se torna uma premissa fundamental para reforçar a sua imunidade e diminuir a dependência dos antibióticos nas granjas. Incentivar sistemas produtivos mais sustentáveis e harmônicos que preconizem o bem-estar animal é uma alternativa promissora às políticas de uso prudente de antibióticos e ao combate a AMR.

Evidências sugerem que a restrição de antibióticos em animais está relacionada à redução de genes de resistência a antibióticos nas bactérias isoladas em ambos, animais e em humanos (NOBREGA et al., 2020). Entretanto, o problema da AMR, assim como de outras zoonoses emergentes, se refere à sua iminência potencial e à dificuldade de predição numérica desses eventos (CHANDLER, 2019), o que fortalece discursos negacionistas e dificulta a obtenção de informações categóricas. LAKOFF (2015) enfatiza a necessidade de se manter uma conduta sentinela em relação às ameaças potenciais para evitar seus danos futuros, e que a AMR se enquadra nesse escopo.

CHANDLER (2019) descreve que os antibióticos fazem parte de uma estrutura complexa que garante a manutenção de saúde e as comodidades da vida humana moderna. Em abordagem semelhante, KIRCHHELLE (2018) enfatiza que a pecuária intensiva foi construída com os antibióticos de alicerce, e que a iminência da AMR e as evidências de que bactérias resistentes em animais podem prejudicar humanos são um prenúncio de colapso para a produção animal. Ambos os autores citados acima nos convidam a refletir sobre todas essas relações que envolvem os antibióticos e de que as políticas de restrição de antibióticos baseadas em atitudes individuais poderão não ser suficientes para resolver o problema da AMR.

O uso de antibióticos veterinários envolve um emaranhado de conexões entre aspectos sanitários, econômicos e sociais. Existe uma rede que se fortalece a partir do crescimento de grupos econômicos consolidados (farmacêuticas, agroindústrias e indústria de insumos) as

quais se retroalimentam e provêm a renda de muitos profissionais. Além disso, o antibiótico é visto por esses atores como garantia de produção e de lucros financeiros, ou seja, os fármacos são uma ferramenta eficiente e confiável. Restringir antibióticos significa interferir nessas relações que não necessariamente envolvem os aspectos puramente farmacológicos dos antibióticos. Por esse motivo, planos de uso prudente não podem se restringir à proibição de promotores de crescimento e restrição de determinados princípios ativos. Políticas de controle de uso de antibióticos veterinários devem prever educação sanitária dos profissionais e dos agricultores, incentivo a melhorias nas práticas de bem-estar animal, investimentos em prevenção, higiene e biosseguridade dos rebanhos para que seja possível reduzir efetivamente o uso de antibióticos na suinocultura brasileira. Além disso é fundamental rediscutir a importância dos médicos veterinários como promotores de saúde, e não como prescritores e vendedores de medicamentos.

O Brasil, como 4º maior produtor mundial de carne suína, faz parte das discussões internacionais sobre saúde e bem-estar animal (TODESCHINI, 2012) e precisa estar atento a todas as mudanças em relação ao uso de antibióticos. Estudos qualitativos que explorem as percepções dos diferentes atores sociais da cadeia produtiva podem auxiliar na identificação dos possíveis trade-offs e na implementação de novas regras de uso de antibióticos.

Objetivos

- Explorar os conhecimentos e atitudes de suinocultores sobre uso de antibióticos (AMU), prevenção de doenças e bioseguridade, assistência técnica, diagnóstico e tratamento de doenças nos suínos.
- Explorar os conhecimentos e atitudes de criadores de suínos sobre comportamento, senciência e bem-estar de suínos e sua relação com AMU;
- Caracterizar as práticas de AMU nas granjas de suínos e explorar as atitudes dos suinocultores em relação a cenários de restrição de antibióticos no Brasil;
- Investigar os conhecimentos, crenças e atitudes de profissionais da cadeia produtiva de suínos a respeito de uso de antibióticos (AMU), AMR e bem-estar animal.

Aspectos metodológicos

Os três capítulos desta tese envolvem estudos qualitativos realizados com suinocultores e profissionais da cadeia produtiva de suínos sobre uso de antibióticos, AMR e bem-estar animal. Todos os estudos foram aprovados pelo Comitê de Ética de Pesquisa com Seres Humanos (CEPSH) da Universidade Federal de Santa Catarina, protocolo nº

As entrevistas com os suinocultores aconteceram presencialmente nos meses de janeiro a março de 2019. Todas as entrevistas foram realizadas em granjas do município de Braço do Norte –SC e região. Os primeiros 12 participantes foram escolhidos a partir da rede de contatos da doutoranda. Os demais participantes foram recrutados por amostragem não probabilística bola de neve, em que um participante indica outros dentre suas relações sociais (ROLLER; LAVRAKAS, 2015). Para o primeiro estudo obtivemos 58 participantes dispostos a responder sobre antibióticos na produção de suínos e para o segundo estudo 44 participantes responderam sobre bem-estar de suínos.

As entrevistas com profissionais da cadeia produtiva animal ocorreram entre março de 2018 e abril de 2019. Os entrevistados foram recrutados através de indicação de informantes, em eventos científicos, redes sociais e contato com órgãos oficiais. Todos 32 profissionais

foram escolhidos de acordo com suas funções profissionais: veterinários e técnicos de campo, zootecnistas, nutricionistas, pesquisadores, professores e veterinários da defesa sanitária animal estadual e federal. As entrevistas foram realizadas pessoalmente, por telefone ou por videochamada, conforme a disponibilidade dos entrevistados.

Todos os participantes receberam um Termo de Livre Consentimento e Esclarecimento e assinaram autorização para gravação. As entrevistas foram transcritas e analisadas com auxílio do software NVivo. O conteúdo transcrito foi lido exaustivamente e deste material surgiram linhas temáticas que nortearam a interpretação de cada um dos trabalhos.

Resultados

No primeiro trabalho com suinocultores (n=58), as entrevistas abordaram uso de antibióticos, biosseguridade e prevenção de doenças, assistência técnica, detecção de doenças e definição de tratamentos, resistência bacteriana a antibióticos (AMR) e consumidores. Identificamos uma baixa adoção por práticas de biosseguridade, evidenciados pelo não tratamento de água de bebida (71%), ausência de controle de visitantes (81%), de veículos (83%) e de vazio sanitário (30%). Os suinocultores consideravam os antibióticos profiláticos como principal forma de prevenção de doenças, principalmente para leitões desmamados e porcas gestantes através de medicação em períodos alternados ("choques de antibióticos"). Aminopenicilinas (41%) e quinolonas (62%) foram os grupos farmacológicos mais citados adotados para administração via ração e tratamentos injetáveis, respectivamente. Os suinocultores definiam os tratamentos através de sua experiência pessoal, mesmo aqueles vinculados às agroindústrias e que recebiam assistência técnica periódica. A relação dos suinocultores com a assistência técnica era baseada em relações comerciais e havia uma desconfiança indicada por parte dos suinocultores quanto à qualidade dos serviços prestados. Um total de 48% dos suinocultores considerou que as granjas de suínos utilizavam os antibióticos de forma adequada, enquanto 43% deles discordou desta afirmação.

Identificamos diversas práticas inadequadas adotadas pelos suinocultores entrevistados, tais como uso de princípios ativos de largo espectro, diluições e doses incorretas e tempo de tratamento insuficiente. Os suinocultores associaram AMR com uso contínuo dos mesmos princípios ativos, mas não com o uso contínuo de antibióticos em geral. Os suinocultores mostraram rejeição a um cenário de restrição de antibióticos no Brasil (63%) justificada por motivos econômicos e pela sua dificuldade de vislumbrar a criação sem o uso profilático de antibióticos. Como os suinocultores consideravam os consumidores desinformados sobre o meio rural (53%) concluímos que eles seriam motivadores fracos de mudanças de conduta quanto ao uso de antibióticos.

No segundo trabalho, as entrevistas abordaram conhecimentos e atitudes dos suinocultores (n=44) em relação à senciência suína, comportamento animal, questões relacionadas ao bem-estar comumente observadas em fazendas intensivas de suínos (*belly-nosing*, brigas, mordedura de cauda, diarreia e castração sem controle da dor) e a concepção e atitudes dos suinocultores sobre o bem-estar dos suínos. Identificamos muitos indicadores de bem-estar precário como o uso de práticas de manejo estressantes e ambientes que limitavam a expressão de comportamentos naturais. No entanto, os suinocultores demonstraram estar satisfeitos com as práticas adotadas em suas granjas, de acordo com sua compreensão sobre bem-estar animal. As percepções dos suinocultores estavam alinhadas com a sua compreensão do bem-estar animal; embora tenham identificado todas as dimensões que impactam o bem-estar de um suíno na granja (afeto, funcionamento biológico e naturalidade), a sua realidade

social, demandas da indústria e os conselhos disponíveis os levaram a perceber sua gama de ação limitada a aspectos biológicos e ambientais, que não necessariamente beneficiam o estado afetivo dos animais. Isso impedia os suinocultores de fazerem associações entre boa saúde e a capacidade do animal de expressar um repertório comportamental completo, bem como de ver comportamentos anormais como indicadores de problemas do sistema de criação. As consequências negativas para o bem-estar dos animais eram comumente aliviadas por rotinas que dependiam do uso constante de medicamentos, incluindo alta dependência de antibióticos.

O terceiro estudo explorou os conhecimentos e atitudes de profissionais (n=32) da cadeia produtiva brasileira de suínos sobre uso prudente de antibióticos, AMR e bem-estar de suínos. Ao final das entrevistas apresentamos um cenário hipotético de uso prudente de antibióticos; os participantes deviam opinar sobre o a viabilidade desse cenário e sugerir as mudanças necessárias para se adotar estratégias de restrição de antibióticos no país. Os entrevistados afirmavam que havia um uso inadequado e abusivo de antibióticos na produção suína no Brasil; porém, 69% deles mostraram atitudes negativas a um cenário restritivo dentro do contexto brasileiro. Esses profissionais apontaram os suinocultores como os principais responsáveis pelo uso imprudente de antibióticos no Brasil, e mostraram ceticismo em relação ao papel da pecuária sobre a disseminação da AMR para os humanos. Além disso, parte considerável dos entrevistados responderam que a redução do uso de antibióticos nas granjas prejudicaria o bem-estar dos suínos. No seu entendimento, a cadeia produtiva de suínos não estaria preparada para prescindir dos antibióticos promotores de crescimento e preventivos de forma abrupta, o que seria justificado por motivos econômicos, sanitários, políticos e culturais. As preocupações com a AMR, bem-estar animal e uso prudente de antibióticos foram considerados por esses profissionais como exigências do mercado e não como premissas indispensáveis na criação de suínos.

Discussão

Percebemos uma forte dependência dos antibióticos por parte dos suinocultores entrevistados, por confiarem nos resultados obtidos com o seu uso e por não investirem em medidas de prevenção de doenças em suas granjas. As práticas inadequadas relatadas mostraram o desconhecimento dos suinocultores sobre a AMR e reafirmaram a importância da educação sanitária e conscientização sobre seus riscos para esse público em particular. Concluímos que os suinocultores não se mostravam motivados e aptos para mudar sua conduta individual de uso de antibióticos, caso políticas de restrição desses fármacos fossem adotadas pelo Brasil em curto prazo.

Do mesmo modo, os suinocultores não se sentiam motivados a adotar mudanças que poderiam beneficiar o bem-estar dos suínos, devido às suas próprias limitações de compreensão do tema a aspectos biológicos e ambientais. Por esse motivo, todas as alternativas apresentadas para melhorar os estados afetivos dos suínos, como por exemplo uso de cama e socialização de leitões neonatos não foram bem acolhidas por esses participantes. Mesmo reconhecendo que suínos são seres sencientes, eles não se mostraram suficientemente interessados em estratégias de redução da dor na castração, por exemplo. Entretanto, tanto em relação aos antibióticos quanto ao bem-estar dos suínos, os suinocultores demonstraram estar sujeitos a normas e decisões alheias às suas vontades, mesmo que a maior parte deles fossem independentes de agroindústrias e cooperativas. Esses resultados sugeriam que fatores econômicos, técnicos do próprio sistema de integração ou cooperativa, e sociais restringiam a autonomia dos suinocultores e sua capacidade de desempenhar o seu papel de guardiões do bem-estar animal.

Por último o estudo realizado com os profissionais da cadeia produtiva animal mostrou que eles, assim como os suinocultores, mantinham relações intrincadas com os antibióticos. Embora os profissionais enxergassem abusos no uso desses medicamentos, eles responsabilizavam os suinocultores pelos desvios e se mostravam reticentes em relação à eficácia de medidas regulatórias. Isso também sugere que esses profissionais não se sentiam como parte do problema da AMR, ou ainda corresponsáveis por tal. Mesmo que eles soubessem o caminho a seguir, não se sentiam motivados ou confiantes a adotar mudanças de conduta e, assim como os suinocultores, também demonstravam falta de autonomia nas decisões.

Considerações finais

As práticas adotadas pelo sistema intensivo de suínos precisam ser readequadas a propostas sustentáveis, principalmente em relação ao uso de antibióticos. Para que o Brasil seja capaz de adequar às normativas internacionais de controle de uso de antibióticos é necessário que se valorizem relações harmônicas entre humanos, animais e ambiente e que se criem os suínos em condições que respeitem seus comportamentos naturais e estados afetivos positivos. Para isso, é necessário que suinocultores e profissionais estejam suficientemente qualificados e abertos a novas formas de criar suínos e levando em consideração práticas de bem-estar animal, com animais imunocompetentes e seguindo com rigor práticas de biosseguridade.

FIGURE LIST

TABLE LIST

SUMÁRIO

1. INTRODUCTION

Reducing the use of antibiotics in human and animal medicine is a goal to be achieved to minimize the negative impacts of antimicrobial resistance (AMR). Seen as a global emergency and potential epidemic for this century by world health agencies such as the UN and OIE, AMR is a natural evolutionary process of bacteria that was facilitated by the indiscriminate use of antibiotics. Antibiotics are tools that anchor complex problems of health, biosecurity and well-being of humans and animals (CHANDLER 2019). To do without this resource in intensive livestock farming, it is necessary to readjust animal production systems that consider animal welfare and the (re)establishment of harmonious relationships between animals, the environment and people – the One Health principle.

In 2021 the world is going through a highly relevant historical moment in which a pandemic of zoonotic origin culminated in great suffering and the death of millions of people around the world. Studies on epidemic projections point to the importance of maintaining a sentinel approach in relation to potential zoonoses (LAKOFF, 2015) and AMR (CHANDLER, 2019). Emerging zoonoses are associated with climate change, intensification and misuse of land and anthropic interference in complex ecosystems, combined with problems of food insecurity, health and inappropriate use of antibiotics (MARCHANT-FORDE; BOYLE, 2020). The complexity of the dynamics of these relationships promotes the spread of bacteria and resistant genes in the environment of immeasurable impact (WOOLHOUSE et al., 2015). The risk of sharing resistant bacteria between humans and animals and the imminence of a new pandemic have put global health agencies on alert and motivate the adoption of public policies for the rational use of antibiotics in several countries.

Pig farming is one of the livestock systems that uses more antibiotics (VAN BOECKEL et al., 2015). In low- and middle-income countries, including Brazil, veterinary antibiotics work as a palliative for structural health and animal welfare problems (VAN BOECKEL et al., 2019). In an attempt to meet international demands to restrict the use of antibiotics without losing productivity, the pig industry searches for a pharmacological substitute for growth-promoting antibiotics that has the same effectiveness and reliability. The structural problems that lead to the indiscriminate use of antibiotics, on the other hand, remain less discussed and without an immediate response. However, the prudent use of antibiotics demands to discuss the rearing models adopted by the pig industry and to bring objective and feasible alternatives, compatible with the reality of farmers.

More harmonious agroecological pig rearing systems can be interesting alternatives to reduce the use of antibiotics. The indiscriminate use of antibiotics in pig farming is related to crucial moments of distress and suffering, when pigs are more vulnerable to pathogens. Improvements in the adoption of hygiene and biosecurity practices are essential to reduce the illness of animals. Promoting positive changes to the welfare of pigs, in addition to improving their quality of life, can contribute to healthier and immune competent individuals for facing potential environmental challenges. There are some studies showing that improving the level of animal welfare leads to reduced need of antibiotics (DIANA et al., 2020; LAVA et al., 2016; RAASCH et al., 2020). Providing more space and environmental enrichment (LI et al., 2021; LIDFORS et al., 2020), gradual weaning (MASSACCI et al., 2020; VAN NIEUWAMERONGEN et al., 2017), and eliminating painful management practices (HÖTZEL et al., 2020) are examples of strategies that can help to reduce stress and potentially maintain health in pig herds with less use of antibiotics.

The negative socioeconomic impacts of AMR and the misuse of antibiotics fall mainly on farmers. Recognizing them as important and interested voices for the use of antibiotics and animal welfare can determine the agreement and effectiveness in the adoption of public measures aimed at combating AMR in Brazil. Likewise, exploring the knowledge and attitudes of professionals in the pig production chain can also help design public policies for the prudent use of antibiotics and for raising awareness among players, as well as identifying potential limitations in adopting these measures. Qualitative studies that investigate the attitudes of these social actors can enrich the debate on the prudent use of antibiotics and fill knowledge gaps in the elaboration of public policies. For these restrictive measures to be effective and have adherence, it is important to bring the narrative to practice and encourage all actors to take ownership of the subject and effectively believe in the message conveyed (BJÖRKMAN et al., 2021).

1.1 OBJECTIVES

1.1.1 General objective

The main objective of this thesis is to explore, using a qualitative approach, the knowledge and attitudes of farmers and professionals in the Brazilian pig production chain on the prudent use of antibiotics, AMR, and animal welfare.

1.1.2 Specific objectives

• Explore the knowledge, attitudes and behaviors of pig farmers about the prudent use of antibiotics, disease prevention, technical assistance and disease diagnosis.

• Explore the knowledge and attitudes of pig farmers about pig behavior, sentience and animal welfare.

• Investigate the knowledge, beliefs and attitudes of professionals in the pig production chain regarding the AMU, AMR and animal welfare.

2. UNDERSTANDING THE RELATIONSHIPS BETWEEN PIG WELFARE AND SUSCEPTIBILITY TO DISEASE IN INTENSE PIG FARMING: A REVIEW

Albernaz-Gonçalves, R.; Olmos, G., Hötzel, M.J

2.1 GLOSSARY

For a better understanding of the text, we define some terms used in the review, based on MCEWEN and WINGFIELD, (2003, 2010), MOBERG and MENCH (2000), ROMERO et al. (2009) and JENSEN, (2014).

- Homeostasis: consists of the balance of the physiological mechanisms that maintain the life of the animals.
- Allostasis: these are all active mechanisms necessary for the maintenance of homeostasis. This concept includes thermal regulation, pH control, cardiovascular pressure, glycaemic control, among others.
- Allostatic overload: occurs in situations where there is an exacerbation of allostatic mechanisms, and the energy required for allostatic mechanisms is greater than the energy available. Consequently, there is a change in the energy flow of some systems to favour others (see also Resource Allocation Theory).
- Stress: physiological responses arising from sensitization of the pituitary-adrenal axis (HPA) and the autonomic nervous system (ANS). It does not necessarily generate distress.
- Distress: "negative stress" due to allostatic overload. Related to mental, social and physical stressors. Related to animal welfare.
- Stressors: environmental or management factors that challenge homeostasis and cause distress.
- Epigenetic factors: mechanisms that interfere in the expression and translation of the animal's DNA, when environmental changes cause changes at the DNA level.

2.2 ABSTRACT

Restrictive, barren housing and many well-established management practices that cause pain and stress predispose high-performance pigs to illnesses. Under these conditions, preventative measures like biosecurity and vaccinations are essential, but not sufficient to ensure high standards of health. In this context, antibiotics are used as part of the infrastructure that sustains high levels of production and health in pig farms. Antimicrobial resistance (AMR) has been recognized as a global emergency of human and animal health. The use of antimicrobials (AMU) in intensive livestock farming is an important risk factor for the spread of resistant bacteria to humans and animals. Tackling the issue of AMR demands profound changes in AMU, including the reduction of AMU for prophylaxis in pig production. To give support to recommendations it is necessary to better understand the link between animal welfare and AMU. Here we review critical management practices that increase stress and pigs' susceptibility to disease. We also discuss some alternatives that can be adopted in pig farms to improve animal welfare beyond the reduction of stress. Our proposition is that by ensuring

optimal welfare conditions and reducing environmental and management stressors, pigs can become immune competent and more prone to overcome most pathogenic challenges of intensive farming. This outcome can contribute to reducing AMU and the risk of AMR and improve the quality of life of pigs and, ultimately, to maintain the pig industry's social license.

Key words: Intensive, management, AMU, AMR, pigs, antibiotics, health, stressors

2.3 INTRODUCTION – AMU/AMR AND AW AS CONCEPTS AND ITS RELATIONSHIP

The discovery of antibiotics was crucial in reducing deaths and infections in animals and in humans. With the expansion of intensive pig and poultry production systems in Europe and at the United States after World War I, pharmaceutical corporations saw in intensive livestock a niche market for antibiotics beyond human medicine (WOODS, 2019). Confinement housing brought along with it, an increase prevalence of respiratory and enteric diseases that affected hundreds of pigs. To address this problem, US pharmaceutical corporations began testing products that could be dispensed through water and feed (KIRCHHELLE, 2018a; WOODS, 2019). By 1940s, it was possible to control diseases and increase productivity, reducing production costs associated with animal feed consumption and labour associated with animal care (KIRCHHELLE, 2018b). This new production model, anchored in the effectiveness of antibiotics, remains in intensive pig farming up to these days (ALBERNAZ-GONÇALVES et al. 2021a; CALLENS et al., 2012; DIANA et al., 2019). Antibiotics are used in three ways in intensive animal husbandry: as growth promoters, in continuous sub-doses in the feed; in therapeutical doses to treat diseases, in this case parenterally or in the feed; and as prophylactics, they are usually administered via feed or water at critical times of stress (ALBERNAZ-GONÇALVES et al., 2021a; BOKMA et al., 2014). Such use of antibiotics allowed to keep herds with high pig densities and to achieve high productivity (WOODS, 2019).

Resistance is a spontaneous process of bacteria that can be accelerated by antibiotics, especially when inappropriately used (WOOLHOUSE et al., 2015). The spread of resistance genes can be spread by vertical transmission (the original bacterial cell transmits the determinant of resistance to the offspring) or via inter and intra-species horizontal transmission (GAJDÁCS et al., 2021). In horizontal transmission, the potential for dissemination is greater due to the mobile genetic elements that can spread in the environment and be incorporated by other bacteria; that is why animals are so relevant AMR reservoirs (GAJDÁCS et al., 2021;

WOOLHOUSE et al., 2015). The transfer of multi-resistant bacteria between animals and humans is a critical concern, and considered by health agencies as a worldwide public health emergency (BOKMA et al., 2018). The contribution of the use of antibiotics in intensive pig farming to the emergence of antibiotic-resistant bacteria in humans raises important ethical, social and public health concerns (MINSSEN et al., 2020; VAN BOECKEL et al., 2015).

To minimize bacterial resistance and promote strategies for prudent use of antibiotics, the FAO, WHO and OIE have created a three-pronged initiative – One Health – that links aspects of human, animal and environmental health into trans-disciplinary public policies. One Health is a holistic health concept that proposes viewing human and animal health as interdependent and at the same time connected with each other and with the ecosystems in which they coexist, in a balanced relationship (VAN BRUGGEN et al., 2019). Good animal welfare can reflect upon humans and the environment by ensuring food safety, improving human health, environmental sustainability, worker safety, rural development, gender equality and social justice (GARCÍA PINILLOS et al., 2016). Animal production systems that aim at sustainability and prudent use of antibiotics must include animal welfare as a goal (VON KEYSERLINGK; HÖTZEL, 2015) and may thus contribute to the promotion of the fundamental global objectives of sustainable development (GARCIA PINILLOS 2018). The OIE encompasses these elements in the *OIE Terrestrial Animal Health Code*, stating that *"An animal experiences good welfare if the animal is healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state"* (OIE, 2019a).

When considering the living conditions of pigs in intensive production systems, we realize that it is challenging to meet the goals of high animal welfare standards and the reduction of use antibiotics. The use of antibiotics in animals without apparent infection often masks problems related to poor housing and management, hygiene, or biosecurity levels (WILLIS; CHANDLER, 2019). The maintenance of poor pigs' welfare and environment conditions could not be sustained without a consolidated antibiotic structure (KIRCHHELLE, 2018a); this, for WILLIS and CHANDLER (2019) underscores the dependence relationship between antibiotics and productivity.

The aims of this review are to establish a relationship between animal stress and heath; then, to identify the main triggers of stress in specific periods of the life of pigs reared in

intensive systems and discuss how they affect pig welfare and health; and, finally, to point out some interventions that can improve the welfare and health of pigs and, potentially, contribute to the goal of reducing the need for antibiotics in pig farming.

2.4 STRESS AS A TRIGGER FOR DISEASE

Understanding physiological processes underlying the stress response and how they influence the pig's immune system and health can shed light on the relationship between pig welfare and the use of antibiotics. Therefore, we will define some relevant terms for this review.

In the first scientific definitions on the subject Selye (1936) proposed that stress is "a non-specific response of the body to any demand for adaptation". A biological alarm response is triggered in environmentally adverse situations or at times when an individual's homeostasis is threatened in some way (SELYE, 1936). However, other more modern scientific proposals argue that Selye's concept of stress and homeostasis is not complete and that other mechanisms need to be better understood (MCEWEN; WINGFIELD 2003; VEISSIER; BOISSY 2007; ROMERO ET AL. 2009). Homeostasis refers to the maintenance of the stability of life-sustaining physiological systems (pH, oxygenation, temperature, blood glucose) (MCEWEN; WINGFIELD, 2003). Allostasis control has the function of compensating imbalances in homeostasis, through the mobilization of energy and other resources for the adaptation/acclimatization of the organism in the short term (ROMERO et al. 2009). Evolutionary mechanisms of allostasis trigger the stress response through the autonomic nervous system and the hypothalamus-pituitary adrenal axis (HPA). This prepares an alarm response, which is activated by the release of adrenocorticotropic hormone (ACTH), which in turn stimulates cortisol synthesis and secretion, with metabolic, cardiovascular and immunological effects. According to MOBERG and MENCH (2000) the stress response can be divided into three stages: the recognition of a stressor, the biological protection against that stressor, and the consequences of the stress response (Figure 1).

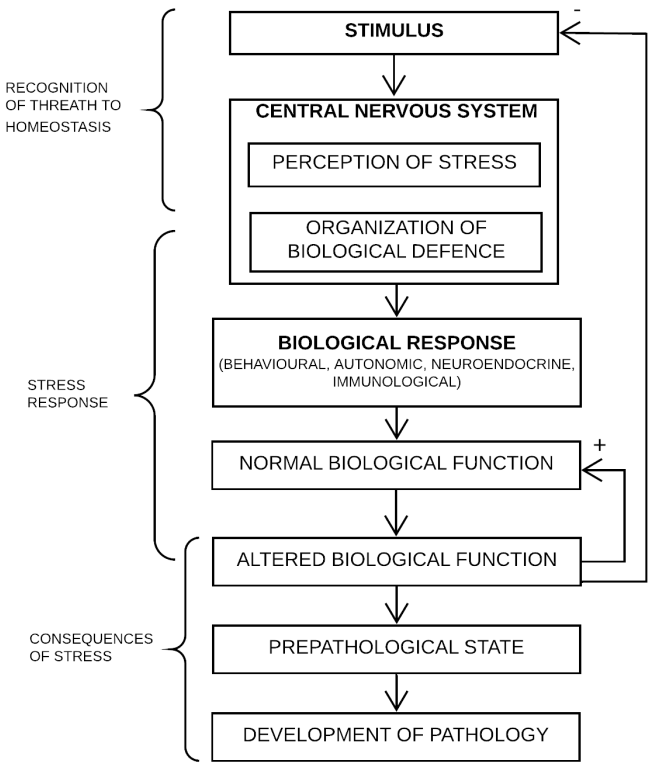
However, it is important to note that stress responses *per se* do not characterize distress; e.g., physiological cycles such as reproduction or lactation can cause changes in these metabolic profiles, likewise, any threats to the animal’s integrity (MCEWEN; WINGFIELD 2010). The daily and seasonal circadian cycles of the animals anticipate additional predictable needs, which are characterized by fluctuations in the animal's physiological state or variations in the environment that may compromise homeostasis.

Harmful stress (herein referred as distress) results from excessive activation of allostatic mechanisms. Situations that trigger responses of allostatic overload (Romero et al. 2009) may cause suffering and reduced animal welfare (BROOM, 1991; MOBERG; MENCH, 2000) and is associated with chronic stress. Even when animals adapt to unfavourable environmental conditions, there may be allostatic overload, interfering with the basic energy mechanisms that maintain growth, reproduction and the immune system (MOBERG; MENCH, 2000). The consequences of this response will determine whether the animal is undergoing a temporary negative experience (i.e., acute stress) or suffering from chronic stress, that latter having effects being the most damaging for the animal's health and welfare (MOBERG; MENCH, 2000).

Psychological stressors are as damaging to the immune system as pathogenic aggressors. The perception of a threat stimulus by the central nervous system triggers a biological defence that activates 4 types of response: a behavioural response, an autonomic nervous system response, a neuroendocrine response and an immune response (MOBERG; MENCH, 2000). Abnormal behaviours in pigs (e.g., belly-nosing, tail biting, tail ear, aggressiveness) are examples of behavioural responses to chronic stress (BARNETT et al., 2001). Brain mechanisms, such as feelings of pain, fear and pleasure are important parts of the animals' coping systems (BROOM, 2008).

Fear plays an important role in adapting animals to their environment, by motivating them to avoid potentially dangerous situations (BOISSY, 1995). Fear influences animal performance and welfare via a classical stress response that involves physiological responses that aim to provide energy for immediate use by the body, in preparation to flee or face aggression (BOISSY, 1995). Therefore, negative human-animal interactions at the farm may contribute to increased susceptibility to disease, by activating energy-costly stress responses (BOISSY, 1995), especially when these interactions are persistent or frequent.

Figure 1. Animal biological stress model proposed by Moberg.



Source: Adapted from Moberg (2000).

Pigs that suffer from chronic stress have a reduced natural ability to set a response to an immune challenge (DE GROOT et al., 2001). Additionally, pig strains genetically selected for high production performance are more susceptible to disease because they allocate metabolic resources for accomplishing physiological demands at the expense of the immune system (RAUW 2012). According to the resource allocation theory, the animal metabolism will always spend the least amount of resources, selecting which metabolic function will benefit through a partition of metabolic resources; when certain resources are consumed by a given metabolic function they are not available for other functions (BEILHARZ et al. 1993). For example, pigs that spend more metabolic resources for growth will have fewer nutrients available for the immune system, resulting in greater vulnerability to disease. As a result, the protein synthesis necessary for growth, reproduction and immune response processes is depressed, and energy reserves are mobilized (MOBERG; MENCH, 2000). This response, which in normal situations usually favours the survival of the individual, can be harmful to the

organism, due to its continuing nature that characterizes the chronic stress to which pigs are often subjected. Therefore, chronic stress is harmful via at least two mechanisms, the deleterious effects of cortisol and the lower efficiency to set an immune response.

2.5 FARM MANAGEMENT AS A STRESSOR FOR PIGS

The concepts and physiological mechanisms that we have reviewed in the previous section can be used to identify potential stressors for pigs reared under intensive conditions and consider how the lack of coping strategies may affect these animals. Thus, in this topic we will address the main causes of stress in pigs reared in intensive conditions, dividing stressors into two types: those derived from the housing environment and those generated by management practices typically adopted in intensive pig farming. The first are related to the physical limitations imposed by intensive housing (e.g., to free movement, socialization and expression of natural behaviours) and to climatic conditions (climatic stress) that can cause discomfort, abnormal or stereotyped behaviour and injuries. The second reviews feeding management, early life management, weaning, transport, human-animal interactions.

2.5.1 Housing stressors

Housing that limits the ability of pigs to move

Restrictive confinement housing restricts the expressing highly motivated behaviours (LAWRENCE et al., 2018). Failure to perform innate behaviours may lead pigs to express abnormal behaviours and other behavioural indicators of distress, frustration and boredom (BRACKE; HOPSTER, 2006; BURN, 2017; MEAGHER, 2019). Psychological stressors are just as damaging to the immune system as pathogenic aggressors. Coping systems are metabolically expensive, and when failures occur, there is an overactivation of neuroendocrine systems that can cause different pathologies due to stress (KOOLHAAS et al., 1999).

Lack of movement can lead to poor cardiovascular conditioning and bone and muscle weakness; in overweight animals, especially the gestating sows, further damages can occur to the health of the limbs (MARCHANT; BROOM, 1996). Sows that lie down for a long time can present limb injuries or pain when moving (HERSKIN; DI GIMINIANI 2018). Locomotor disorders such as lameness in heavy sows may result from physical damage to the limbs, as well as infectious arthritis or osteochondrosis (BOS et al., 2016; JENSEN; TOFT, 2009). Factors such as nutrition and characteristics of the floor are known risk factors for these

disorders (NALON et al., 2013). Sows are more prone to limb injuries and lameness due to weight changes during pregnancy (VECEREK et al., 2020). These conditions are risk factors for reduced sow longevity (PLUYM et al., 2017) and important causes of sow premature culling (BERGMAN et al., 2018; VECEREK et al., 2020).

As pregnancy progresses, the limbs become heavier and sows have more difficulty moving because of the pain, which predisposes to sows remaining in the sitting dog position longer and reducing feed and water consumption (PLUYM et al., 2017). Reductions in the frequency of urination, as well as faecal contamination of the perineal region, predispose sows to bacterial urinary infections (DROLET, 2019; PLUYM et al., 2017). Urinary tract infections cause reproductive sow disorders, such as reduced litter size, return to oestrus, abortion, anoestrus, and predisposition to mastitis-metritis-agalactia syndrome (GERJETS et al., 2011; GERJETS; KEMPER, 2009). There is a positive correlation between genito-urinary infections in sows and the incidence of diarrhoea in neonatal piglets (MARADIAGA et al., 2018). At birth, pathogens are shared between the mother and the offspring that will promote the formation of piglet flora (MARADIAGA et al., 2018; PLUSKE et al., 2002). Continuous farrowing systems accumulate bacteria in the farrowing environment, and the inadequate hygiene of these facilities can be the cause of diarrhoea outbreaks (FAIRBROTHER; NADEAU, 2019). *E.coli* is the most common bacterium in genito-urinary and puerperal infections in sows (GERJETS; KEMPER, 2009; MORENO et al., 2018). Broad-spectrum antibiotics are used as a preventive to genito-urinary infections of sows (LI, 2017) and for diarrhoea in newborn piglets (UNTERWEGER et al. 2018). Additionally, genito-urinary infections are causes of reduced sows' longevity on farms (HEINONEN et al., 2013; VECEREK et al., 2020).

Fattening pigs are also susceptible to locomotor problems. Severe lameness can progress to severe locomotion problems and bone fractures, resulting in some cases of culling or euthanasia on the farm (JENSEN et al., 2012). Limb lesions change according to the age of the pigs, with older pigs developing bursitis, hock swelling and calluses due to increased pressure due to weight, and young pigs developing abrasion lesions or bruises from lack of support on slatted floors (KILBRIDE et al., 2009). Lameness in fattening pigs is an animal welfare problem as serious as in sows and the third most common cause of antibiotic use on farms (CHRISTENSEN et al., 1994; JENSEN; KRISTENSEN; TOFT, 2012).

Housing that limits exploratory behaviour and normal social interactions

Strict confinement prevents pigs from express their exploratory behaviours (WOOD-GUSH; VESTERGAARD, 1989). The lack of environmental stimuli and the inability to carry out species-specific behaviours can cause frustration, which can manifest itself through negative behaviours or apathy (MELLOR et al., 2020). Monotonous environments can also generate frustration and negative behaviours that can be directed at penmates or be self-inflicted (MEAGHER, 2019). Belly-nosing, tail biting and ear biting of pen mates are examples of oral behaviours redirected by frustration and boredom (PRUNIER et al., 2020).

The oral behaviour belly-nosing is a form of redirected sucking behaviour (BLOKHUIS et al., 2007; JOHNSON et al., 2019), and is further motivated by barren environments (DYBKJÆR, 1992). Belly-nosing can result in skin lesions on the recipient's belly and flank, causing skin ulcerations; therefore, it indicates negative emotions both in the piglet that receives the interaction, due to injuries and pain and difficulty to rest, and the piglet that performs the behaviour (SINGH et al., 2016).

Tail biting is a major welfare problem and an important source of post-mortem condemnations (VOM BROCKE et al., 2019). The resulting damage from tail biting can range from a bite mark to a serious injury and, in more serious cases, can cause the bitten pig to die (VALROS, 2018). Injuries due to tail biting cause significant financial losses; severely bitten pigs have reduced weight gain and lighter carcasses, and in some cases carcasses may be condemned for serious injury (TEIXEIRA et al., 2016). Partial tail docking of piglets at birth is the most commonly used practice to prevent tail biting (EFSA, 2007) although this practice is prohibited in several countries. Nevertheless, studies have shown that tail docking is not sufficient to eliminate biting behaviour when pigs continue to be challenged by a stressful environment (DI MARTINO et al., 2015; SCOLLO et al., 2013), and when piglets have the tail docked the behaviour may be redirected to other parts of the body (DI MARTINO et al., 2015).

Aggressive agonistic interactions are often related to hierarchical disputes due to inappropriate mixtures of unknown animal groups (GREENWOOD et al., 2014; PEDEN et al., 2018). Inadequate social interactions and abnormal behaviours are common among piglets immediately after weaning, one of the greatest stressors in a piglet’s life (WEARY et al. 2008). As reviewed by Turner et al. (2018), the aggressions resulting from the mixture of unfamiliar animals cause a physiological response by activating the HPA axis, release of cortisol and

impaired immune response. Furthermore, skin lesions predispose pigs to infections (PLUSKE et al., 2003; TURNER et al., 2018).

Aggressive behaviours may be frequent in group-housing gestation sows. This type of housing is presented as an alternative to more restrictive housing systems, as it can improve the mobility of pregnant sows and promote social interactions (NORRING et al., 2019; SCHEEL et al., 2017). However, poor planning and poor management can cause stress on pregnant sows. Stressors associated with group gestation systems are related to management of dynamic groups, resource availability and access, and disputes over resting areas (RUTHERFORD et al. 2013). For example, increased fighting and aggressiveness within the group of sows may be observed when food is not supplied simultaneously to all the sows (BENCH et al., 2013a; STEVENS et al., 2015). Aggressive interactions occur whenever a new group of pregnant sows is housed and the frequency declines as the group's social hierarchy is established (BOS et al., 2016). The formation of different groups of sows increases agonistic interactions in the prenatal period. When mixed, late-weaning or newly weaned sows may show submissive behaviours, evidenced by increased body lesions, reduced feed consumption and weight gain (JARVIS et al., 2006b).

Housing that limits the expression of nesting behaviour

The deprivation of nesting behaviours is also a source of distress and frustration. Sows reared in extensive or semi-natural environments seek a suitable place to build a nest 24 hours before farrowing (JENSEN, 1986). Although genetic selection has changed some productive traits of modern pig lines compared to their predecessors, motivation for nesting was unchanged (GUSTAFSSON et al., 1999). Farrowing crates are designed to facilitate management and to minimize piglet mortality by crushing. However, sows confined in crates before farrowing show restlessness, frequent changes in body position, intermittent grunts, grinding teeth, and bite bars and parts of the crates (HÖTZEL et al., 2005). Deprivation from nesting can increase aggressiveness, especially in primiparous sows (BARNETT et al., 2001). Sows of multiple parities may be less reactive in farrowing crates cells; however, these sows demonstrate abnormal HPA axis activity just as younger sows (JARVIS et al., 2001).

Epigenetic factors may contribute to aggressiveness in sows. Some studies showed that social distress in gestating sows can affect the offspring (COURET et al., 2009) because the mother determines the responsiveness of the piglets' hypothalamus-pituitary-adrenal axis

(HPA) (JARVIS et al., 2006a). The daughters of stressed sows, like their mothers, are more restless during farrowing, more reactive and bite more their piglets (JARVIS et al., 2006a, 2006b). Piglets born to stressed sows during pregnancy also have reduced immune capacity and are more susceptible to infections during lactation and pre-weaning (COURET et al., 2009). Some studies have shown that prenatal stress alters the offspring phenotype, compromising the maternal behaviour of the gilts as adults (RUTHERFORD et al. 2014). Stress in pregnant sows maintains high levels of glucocorticoids, which cross the placental barrier and may affect the foetal HPA axis maturation through hippocampal cell death and loss of cognitive functions (JARVIS et al. 2006).

Housing that causes thermal stress

Pigs have peculiar morphological characteristics that make them susceptible to thermal stress. The absence of loose skin and the lack of sweat glands, which are restricted almost entirely to the muzzle, are factors that help the pig body heat to build up at high ambient temperatures (Fraser 1970). The thick layer of subcutaneous adipose tissue, added to poor panting ability, are impediments to heat loss in the species (ROSS et al., 2015). Pigs from high-performance strains, even kept in thermo-neutral conditions in the fattening phase, showed total body heat production 26% higher compared to other breeds (BROWN-BRANDL et al. 2001). One reason for this is that pigs have been selected for lean tissue, which changed the relationship between body fat and protein, and protein accumulation generates more body heat (BROWN-BRANDL et al., 2001; ROSS et al., 2015). The same principle can be inferred from genetic selection for prolificacy, as increased offspring production also increases heat production via protein deposition (ROSS et al., 2015).

The thermal comfort zone, which is the ambient temperature range in which the thermoregulatory effort is minimal, is variable for each pig and depends on the amount of endogenous heat produced. There are important variations in the production and range of environmental thermal tolerance at different ages, weights and physiological stages (KYRIAZAKIS; WHITTEMORE, 2006). Environmental conditions such as temperature, wind speed, relative humidity and floor type should be considered to determine the appropriate temperatures of an environment that seeks the thermal comfort of pigs (BRUMM, 2019).

The physiological response to thermal stress is similar to the chronic stress response presented by Moberg and Mench, (2000) and discussed earlier in this review. In order to

maintain thermal homeostasis, neural regulatory mechanisms are triggered that connect information from the internal and external environment to an efferent response, such as vasoconstriction, pylorization or shortness of breath (NAKAMURA; MORRISON, 2008). Thermal stress triggers central, peripheral and endocrine nervous systemic responses in order to prepare and make available resources to meet compensatory emergency demands and maintain homeothermy (COLLIER; GEBREMEDHIN, 2015). The hypothalamus releases corticotropin-releasing hormone and vasopressin arginine. Peripheral receptors are skin thermoreceptors and retinal photoreceptors that drive autonomic and endocrine nervous system responses to thermal changes in the environment (COLLIER et al., 2019). Warm-blooded animals exchange heat through sensitive or latent heat routes (COLLIER et al., 2019). ROSS et al. (2017) described two harmful physiological mechanisms that result from thermal stress: a first mechanism is associated with hormonal imbalance and affects aspects of reproduction; and a second that involves an increase in inflammatory pro-cytokines that compromise intestinal integrity.

2.5.1.1.1 Heat stress

Heat-stressed pigs are also more susceptible to infections due to immunosuppression (MORROW-TESCH et al., 1994; YONG et al., 2019). Thermal stress during pregnancy is harmful to sows and piglets; thermal stress in-utero impairs the immune response of piglets at birth, which can affect pre-weaning health and survival (JOHNSON et al., 2015; OTTEN et al., 2015).

Exposure to thermal stress for long periods stimulates the activity of the HPA and hypothalamus-pituitary-gonadal axes, triggering the stress reactions described in item *Stress as a trigger for illness*. In addition, increased insulin levels and the activation effects of the pituitary-gonadal axis provide negative feedback on GnRH, inhibiting reproductive function (ROSS et al., 2017). Heat stress in pregnant sows is reflected in many problems such as return to oestrus, embryonic losses, reduced fertility, delayed uterine growth and the birth of very small piglets (HE et al., 2019; ROSS et al., 2015). Heat-exposed primiparous sows are more susceptible to abortion (IIDA; KOKETSU, 2015). In the last third of gestation high foetal energy demands and hormonal changes make sows more susceptible to heat stress (RUTHERFORD et al. 2013). Heat stress can interfere with embryonic development, litter size and weight, and in some extreme cases, result in sow's death (OMTVEDT et al., 1971).

Excessive heat during pregnancy causes metabolic and uterine blood flow changes that cause permanent deleterious effects on piglets' growth and development (BODDICKER et al., 2014). The regulation of maternal-foetal cortisol is one of the main determinants metabolic and behavioural changes in the progeny (OTTEN et al., 2015). Intrauterine stress may altered growth, plasma glucose and subcutaneous carcass fat thickness (BODDICKER et al., 2014). It may also lead to alterations in neuroendocrine and behavioural patterns, resulting in phenotype with greater reactivity of the hypothalamus-pituitary-adrenal axis, altered emotionality, fear and disturbed maternal and social behaviour (OTTEN et al., 2015).

Heat stress can also affect lactating sows and newborn piglets. Sows subjected to heat stress have increased ACTH, reduced oxytocin and prolonged duration of farrowing which may result in a reduction in the circulating blood supply in the mammary epithelium (NUNTAPAITOON et al., 2019). It is also known that heat-stressed sows are slow to release colostrum and are more susceptible to syndrome metritis-mastitis-agalaxia (BAUMGARD; RHOADS, 2013), which may hinder the growth and development of the immune system of newborn piglets (HASAN et al., 2019).

Heat stressed pigs are more prone to enteritis. When trying to dissipate body heat, blood flow from the viscera to the periphery deviates, causing intestinal hypoxia, ATP depletion and oxidative stress of enterocytes (ROSS et al., 2015). Oxidative stress destabilizes the intestinal barrier, making it permeable to gram-negative bacteria and other antigens (MAYORGA et al., 2020). Changes at the intestinal level during heat stress also provide the establishment of disease-causing pathogens, some of which could be zoonoses and therefore serious public health threat (YONG et al., 2019) including infections with antibiotic resistant bacteria.

Some researchers has discussed the effects of state global warming on thermal stress in farm animals (BAUMGARD; RHOADS, 2013; LEINONEN, 2019; SCHAUBERGER et al., 2019). With increasing global temperatures and large thermal amplitudes, it is evident that confinement housing needs to be designed to minimize the effects of thermal stress, for example by including thermal control mechanisms or increasing the space per animal. In regions most affected by extreme summer thermal conditions pigs are more likely to experience productive and welfare problems due to heat stress (ROSS et al., 2015; SCHAUBERGER et al., 2019).

2.5.1.1.2 Cold stress

Cold stress is an equally important concern, especially during the neonatal and weaning periods. Newborn piglets lose heat quickly after birth. In an attempt to maintain body heat, newborn piglets enter a negative energy balance, due to the low reserves of body fat and glycogen, which are insufficient to meet the energy demands (THEIL et al., 2014). Finding the udder is crucial for piglet survival, as colostrum will provide warmth to neonates (ALEXOPOULOS et al., 2018). Weak or delayed piglets consume less colostrum and are more susceptible to diarrhoea, which increases neonatal mortality and the use of antibiotics to control neonatal diarrhoea (NUNTAPAITOON et al., 2019). One study showed a 14ºC difference in surface temperature between piglets that immediately suckled colostrum and low-viability piglets without access to colostrum (ALEXOPOULOS et al., 2018).

Pigs, including breeding sows and fattening pigs, are sensitive to variations in temperature. For instance, thermal fluctuations influence heat dissipation and body surface evaporation, predisposing pigs to respiratory infections (YEO et al., 2019). In winter, lower temperatures may increase ammonia concentrations within the housing facilities; environmental ammonia causes irritation and changes in the respiratory mucosa, which also leads to respiratory infections (MICHIELS et al., 2015; WANG et al., 2021).

Thermal stress from both cold and heat is an important stressor associated with transport of weaned piglets. Thermal variations during travel can increase the stress level of piglets and affect their recovery after weaning (ROLDAN-SANTIAGO et al., 2013); high temperatures during travel may increase the risk of dehydration (ROLDAN-SANTIAGO et al., 2013; SUTHERLAND et al., 2014), while cold-exposed piglets enter hypothermia and take time to recover when they reach their destination (SUTHERLAND et al., 2014).

2.5.2 Common management practices as stressors

Feeding management strategies as a source of negative stress

Feed restriction in pigs is a widely used management practise used to limit weight gain in breeding sows or for compensatory gain purposes in fattening pigs. Sows' diets are designed to limit caloric intake and excessive weight gain during gestation (D′EATH et al., 2018). Sows are usually fed twice a day, and consume low-fiber concentrated food quickly, which is not enough to maintain their satiety; thus, sows remain hungry and highly motivated to seek food (BERNARDINO et al., 2016; D′EATH et al., 2018). Chronic hunger stress can induce the

expression of redirected and stereotyped oral behaviours (BENCH et al., 2013a). Unable to forage, stressed sows bite cage parts, exhibit sham-chewing, smell and lick the floor and other parts of their cages excessively (BENCH et al., 2013b). In group housing, hunger may lead to an increase in competition for feed and agonistic interactions (BENCH et al., 2013b). There is a correlation between competition for space at the food trough and incidence of tail biting, which can also appear in very large groups of sows in group gestation housing (VALROS, 2018).

Gastric ulcerations are a very common cause of growth failure and sudden death in fattening pigs and breeding sows (GOTTARDO et al., 2017; WITTE et al., 2017). Risk factors include feed particle size, gastric microbiota composition, hormonal changes, and *Helicobacer suis* infection (WITTE et al., 2017), and chronic stress. A study with rats correlated changes in central dopamine levels with a higher frequency of alert behaviour and a higher incidence of gastric ulcerations (GLAVIN, 1993). Some examples of stressors related to these lesions are associated long fasting periods, chronic hunger, thermal variations and disease outbreaks (DOSTER, 2000; FRIENDSHIP, 2004). The prevalence of gastric ulcers in slaughterhouses can vary between 32% to 65% (PERALVO-VIDAL et al., 2021), but it may be underestimated, as they are often subclinical, and detected in slaughterhouses.

Feed restriction during the growing and fattening periods – done either by reducing the amount of feed or specific nutrients in the diet – is used as a way to decrease fat in pig carcasses at slaughter and to stimulate compensatory weight gain in low birth weight piglets (MADSEN; BEE, 2015). Compensatory growth is a physiological phenomenon that occurs after hypercaloric food return, following periods of food restriction or undernutrition (ZHANG et al., 2021a). Feed restriction is a strategy widely used in fattening farms to decrease the fat content of carcasses (MADSEN; BEE, 2015), improve feed conversion and reduce feed costs (ZHANG et al., 2021a). Compensatory growth occurs when a pig that has undergone a period of nutritional stress is fed ad libitum (PLUSKE; et al., 2003). From a physiological point of view, compensatory growth depends on the severity of food restriction, its duration and the age of the animal (PLUSKE et al., 2003). From an economic point of view, food restriction is considered acceptable when the cost of food is lower in the compensatory period (KYRIAZAKIS; WHITTEMORE, 2006), but keeping pigs without food or nutrient deprivation exposes pigs to unnecessary stress.

Beta-agonist compounds such as ractopamine are used as feed additives in some countries to increase lean carcass and lean mass (KARRIKER et al., 2019) by promoting weight gain with greater protein deposition efficiency (MITCHELL, 2009). These compounds act on lipid and muscle tissues beta-agonist promote lipolysis, lipogenesis suppression and muscle hypertrophy (RITTER et al., 2017). However, the consumption of beta-agonist compounds may be associated with increased incidence of pre-slaughter swine and non-ambulatory pig stress syndrome (GRANDIN, 2017; RITTER et al., 2017), and is related to greater difficulty in handling these animals due to increased excitability caused by ractopamine (GRANDIN, 2017). Other behavioural changes identified in pigs consuming ractopamine include increased aggressiveness, fighting and sham-chewing (POLETTO et al., 2010b) these atypical behaviours are a consequence of changes in neurotransmitters essential for aggression control and by alterations in serum concentrations of dopamine, serotonin, norepinephrine and epinephrine (POLETTO et al. 2010a; POLETTO et al. 2010b). Thus, the effects of feeding beta-agonist compounds to pigs needs also be considered in relation to the welfare of fattening pigs.

Early life management

Experiencing pain and stress starting exceedingly early in the pigs' lives. Deleterious effects of these managements on the health and well-being of pigs have sparked discussions about these practices. Besides the ethical issue of causing pain in newborn animals, the pain and stress associated to these managements caused is a gateway to neonatal infections and, consequently, to the excessive use of antibiotics in piglets.

2.5.2.1.1 Painful practices

Pigs experience pain due to disease, management failures, poorly designed environments and negative human-animal interactions. Besides, some painful management practices are performed during the first days after birth often without any use of analgesia (SCHMID et al., 2021). The main painful practices are teeth clipping or resection, tail docking, ear notching for identification, iron injection and castration of male pigs (MARCHANT-FORDE et al., 2014). They are usually done simultaneously and, it can be said that they serve to minimize problems caused by intensive production systems, such as large litters, high stocking density, successive social mixtures, lack of contact with soil, and barren environments.

Teeth clipping is the removal of canine teeth using pliers or other sharp objects. This practice is done to minimize biting injuries to the sow's udder or possible fights over teat

disputes between littermates (ISON et al., 2016). It is performed a few hours after birth, is extremely painful and can cause injury to the piglet's mouth (HERSKIN; DI GIMINIANI, 2018). An alternative is the abrasive grinding of the sharp end using an electric whetstone grinder (BAXTER et al., 2013). Although the bites caused by piglets' teeth are harmful, teeth clipping and wearing increase the piglets' cortisol levels (MARCHANT-FORDE et al., 2014) and can be a gateway to neonatal infections (ISON et al., 2016). Some studies suggest that both practices are harmful and stressful to the piglet and can result in lower weight gain in early lactation (BAXTER et al., 2013).

Tail docking is intended to reduce the incidence of tail biting and can be done with sharp objects or cauterizers and is usually performed without the aid of analgesia or anaesthesia. Tail docking is painful (TALLET et al., 2019), and pigs with an amputated tail experience pain that resembles neuropathic pain reported in humans (DI GIMINIANI et al., 2017a). This means that pigs experience persistent pain on the incision site long after and despite the fact the tail tissue has healed (DI GIMINIANI et al., 2017b). Besides acute pain and stress, tail docking may have adverse consequences on human-animal relationships via a fear response (TALLET et al., 2019).

Male piglets are usually castrated in the first week of life to eliminate boar taint in the meat of slaughtered pigs, caused by the volatile substances androstenone and skatole that accumulate in male pig fat (PATTERSON, 1968). Surgical castration is routinely performed without anaesthetic causing piglets to exhibit higher cortisol levels immediately after the procedure. The most common castration method is a technique that tears the sperm tissue without analgesia, which causes tissue damage and severe pain (SCHMID et al., 2021). Such effect effects confirms that castration is a painful and stressful experience to piglets (HERSKIN; DI GIMINIANI, 2018).

2.5.2.1.2 Cross-fostering and artificial lactation

With the selection of hyper prolific pig strains, the greater number of piglets born was accompanied by high variability of piglet weight at birth and increases in neonatal mortality rates (BAXTER et al., 2013; HEIM et al., 2012). Cross-fostering and artificial feeding are used to recover small and slow growing piglets or to equalize litters. Cross-fostering consists in separating the newborn piglets by weight and distributing them in nursing sows according to

piglet size and sow's milk production (DÍAZ et al., 2018; PAJŽLAR; SKOK, 2019). Artificial suckling is done with automatic systems for 2 and 14 day old piglets, which provide heat and feed to piglets (SCHMITT et al. 2019).

However, cross-fostering and artificial feeding may have negative impacts on the health and welfare of newborn sows and piglets (BAXTER et al., 2013). It is recommended that the of piglets fostered be performed between 14 and 24 hours postpartum, while the teat order is not yet established and that allows colostrum to be absorbed by piglets (ZHANG et al., 2021b). However, in practice, the cross-fostering is done after 7 days postpartum (DÍAZ et al. 2018). With each group change the teat order needs to be re-established, which can be stressful and have detrimental effects on piglet survival, growth and behaviour (BAXTER et al., 2013). Adopted piglets may have their growth impaired due to fights over teats and shorter feedings (KOBEK-KJELDAGER et al., 2020). Piglets transferred between 2 and 7 days postpartum or transferred to groups with older piglets have difficulty integrating, exhibit more ambulation and vocalizations, taking longer time to suckle (PAJŽLAR; SKOK, 2019; PRICE et al., 1994). In addition, sows may be more aggressive with late included piglets (PRICE et al., 1994). Cross-fostering may also affect the welfare of lactating sows, and nurse sows may reject the litters (KOBEK-KJELDAGER et al., 2020).

It is important to consider the transmission of pathogens in late cross-fostering. Newborn piglets that have not yet received maternal antibodies and by mixing them with older piglets they get exposed to pathogens to which they are not protected, increasing the risk of infection (HEIM et al., 2012). Yet, early cross-fostering may be equally harmful to piglets because colostrum production and concentration of colostral immunoglobulins reach their peak within 14 hours postpartum; thus piglets that are transferred before this time will not have received sufficient colostrum amounts, which makes them more susceptible to environmental pathogens (ALEXOPOULOS et al. 2018; DÍAZ et al. 2017).

Low birth weight piglets may be separated from their mothers and placed in automatic devices where they will be heated and given milk, which will gradually be replaced by solid food (RZEZNICZEK et al., 2015). This early weaning deprives the piglets of contact with the dam (SCHMITT et al. 2019). Even if these piglets can develop and often reach a body weight similar to other piglets, they exhibit abnormal behaviours indicative of negative affective states, such as belly nosing (RZEZNICZEK et al., 2015). Other behaviour changes seen are an

increased frequency of belly and flank bites, greater aggressiveness in post-weaning mixtures, in addition to other physiological effects such as changes in cerebral neurobiology and HPA axis activity (BAXTER et al., 2013).

Another animal welfare problem associated with cross-fostering is the late weaning of weak piglets. These piglets take 7 to 21 more to be weaned, that depending on the weaning performed. Regardless, these weak piglets are maintained with a nursing dam or artificially nursed while being mixed with smaller piglets of similar weight (BAXTER et al., 2013). Thus these piglets become a disease risk to the younger pigs they get mixed with (ZHANG et al. 2021).

2.5.2.1.3 Weaning stress

The time the piglets stay with their mother has important physiological and psychological effects on the piglets' development. Under natural conditions the piglets are gradually weaned, completely separating from their mother between 17 and 20 weeks of age (JENSEN, 1986). Under intensive conditions, this process is shortened, and weaning is done abruptly, between 3 and 5 weeks of age. Such strategy practised in intensive farms eliminates or shortens important stages of the physiological and emotional development of piglets.

Early weaned piglets are subjected to the simultaneous social and psychological stress of being separated from mother and siblings and being mixed with unfamiliar animals, losing milk, moved to a new environment and often transported between farms (WEARY et al. 2008). This stress is evidenced by HPA axis activity, which causes changes in the sympathetic nervous system and hormonal profiles that influence the future development of piglets (SUTHERLAND et al. 2014). ACTH and catecholamines can influence the adhesion of pathogens to the GIT membrane, predisposing stressed piglets to diarrhoea (see review, MODINA et al. (2019). All of these factors can lead to transient anorexia, intestinal inflammation, gut microbiota disorders and behavioural disorders that affect the health and welfare of weaned piglets (PLUSKE et al.1997). Post-weaning feeding behaviour, gastrointestinal tract (GIT) development and the establishment of a healthy commensal microbiota are responsible for the integrity of the intestinal mucosa and its flexibility as a defence barrier against aggressors (BISCHOFF, 2011).

Early weaning also has negative effects on the growth, cognitive development and behaviour of piglets (TELKÄNRANTA; EDWARDS 2017; WEARY et al., 2008). From an

emotional point of view, the early negative experience of maternal separation has effects on the hippocampus, so that early weaned piglets have behavioural and cognitive impairment (MCLAMB et al., 2013; POLETTO et al., 2006). Psychological and physical stressors associated to weaning not only cost energy but and impair food consumption and a successful adaptation to the new environment (DEAK, 2007; HÖTZEL et al., 2011). Sick and feverish piglets, in an attempt to conserve body energy, reduce their activity, to remain lying down and without feeding (AUBERT, 1999; DANTZER, 2004; HART, 1988). Thus, for the first week after weaning piglets lose weight, and weak piglets and more susceptible to infections.

Transportation

With the growing trend of pig production being done at specialized breeding sites, piglets are transported for many hours to their destination. Every year millions of weaned piglets aged 17 to 35 days are transported over long distances. The way this transport is carried out can have a significant impact on the welfare of these piglets (LEWIS, 2008). There is a knowledge gap regarding this topic, as the scientific literature refers more often to the transport of pigs at slaughter age. However, it is understood that the stress factors during transport are the same in young and adult pigs, with the aggravation of frailty of younger animals and the concurrent weaning stress of piglets. Transport stress is acute, followed by dehydration and protein catabolism (RIOJA-LANG et al., 2019). Many factors are stressful during transportation, including temperature variation, mixture of unknown animals (SUTHERLAND et al., 2010), hunger and thirst, loading and unloading, vibration and noise handling (SUTHERLAND et al., 2014). Travel time also affects the welfare of piglets during and after transport (ARNDT et al., 2019). Piglets transported between 12 and 24 hours are more prone to dehydration (LEWIS, 2008). Transport speed can also be detrimental to the piglets; in too fast displacements the piglets often lie down and stand up, indicating imbalance and vulnerability to falls (RIOJA-LANG et al., 2019).

Importantly, transport can be a pathogen carrier. Site segregation of piglets is justified by reduced vertical disease transfer, increased productivity and overall efficiency of the farm (SUTHERLAND et al. 2014). However, the mixture of piglets from various origins provides pathogen transfer between animals. Other epidemiological aspects should be considered, including the emission of contaminating particles and the spread of resistant bacteria during

transport (RIOJA-LANG et al., 2019). The transmission of disease through mixtures of different origins and transport is an important knowledge gap.

Fasting associated to transport also causes deleterious effects on the health of weaning piglets. Pigs can lose about 4% of their body weight fasting for 18 to 24 hours, causing catabolism of body reserves over 24 hours (GARCIA et al., 2015; RIOJA-LANG et al., 2019).

Human-animal interactions and fear

The quality of human-animal interactions should be included as one of the predictors of quality of life for pigs. Pigs and humans communicate through acoustic, visual, tactile and chemical sensory channels (TALLET et al., 2018). Although many routine interactions may appear innocuous, aversive human contacts can trigger fear in animals (HEMSWORTH, 2003). The way in which this communication takes place can evoke conflicting or pleasant feelings. Thus, the animals' memory is a central element in the perception of quality of these interactions (TALLET et al., 2018), since many studies have shown that animals have the ability to recognize specific gestures and recognize aversive handlers (BRAJON et al., 2015; NAWROTH et al., 2013; SOMMAVILLA et al., 2011).

The reaction of the pigs to the presence of a specific stockperson may indicate their experience and ability to deal with animals (HEMSWORTH, 2003). Caregivers who are more attentive to animals can be more empathetic and willing to adopt changes that improve the welfare of pigs. In addition, gentle and pleasurable interactions with animals can decrease stress and reduce behaviours that denote fear and anxiety. Behavioural fear reactions can be dangerous to the physical integrity of the keepers and a risk to the health and welfare of pigs.

2.5.3 Problems related to pre-partum stress and sows hyper prolificity

The stress of pregnant and parturient sows may have an influence on neonatal mortality and piglet weight. The birth of weak piglets occurs for several reasons, among them the acute stress of pregnancy, the hyper prolificity of sows and the excess body fat of sows, which affects insulin metabolism and impairs foetal growth (RUTHERFORD et al. 2013; SUPERCHI et al. 2019). Prenatal stress in sows can impair growth and modify immune function, stress reactivity and the behaviour of the offspring (BAXTER et al., 2011).

Hyper prolificity and low birth weight are important points of vulnerability for the occurrence of infections in sows and piglets. Although the hyperprolificity of sows is a highly

selected characteristic in pig herds, it is not always reflected in a higher survival rate of newborn piglets. Hyperprolific sows generate more viable eggs, however, the limitations of intrauterine space increase foetal competition, which can mean more stillbirths or piglets with low birth weight (FOXCROFT et al., 2006; LANFERDINI et al., 2018; VANDERHAEGHE et al., 2013). It is estimated that hyperprolific sows have losses of between 3 and 8% of piglets stillborn due to infectious and non-infectious causes (VANDERHAEGHE et al., 2013). Hyperprolificity can also affect the health status of sows. A retrospective study of Swedish pig herds correlated the increase in litter size with an increased need for treatments such as antibiotics and oxytocin in sows due to puerperal infections (ANDERSSON et al., 2020).

The survival of newborn piglets also depends on an adequate intake of colostrum (CABRERA et al., 2012). Nursing is a critical period for the piglet's immune development, and sow's colostrum is its only source of antibodies for the newborn (DECALUWÉ et al., 2014; DECLERCK et al., 2016). Finding the teat is crucial to piglet survival, as it is colostrum that will provide heat energy to the newborn (ALEXOPOULOS et al., 2018). Low birthweight piglets have a low body energy supply, suck less colostrum and are more likely to die from heat loss, starvation or crushing (MUNS et al., 2016; RUTHERFORD et al., 2013a). A delay in the motor development of these piglets decreases their reflexes and motor coordination, making them unable to defend themselves from crushing (ROELOFS et al., 2019). The supply of colostrum also depends on how much the sow is able to produce. The length of farrowing, body condition and age of the sow can influence colostrum production. Overweight sows with prolonged farrowing produce less immunoglobulins (HASAN et al., 2019), and gilts produce less colostrum and with a lower concentration of immunoglobulins compared to older sows (ALEXOPOULOS et al., 2018; HUTING et al., 2019). Weak piglets that take too long to nurse consume less colostrum and are more susceptible to diarrhoea, which increases neonatal mortality (NUNTAPAITOON et al., 2019).

2.6 IMPROVING HOUSING ENVIRONMENT AND MANAGEMENT TO REDUCE STRESS

During the past decades many changes in housing and management that may minimize or eliminate the environmental stressors have been proposed and tested (PEDEN et al., 2018). In this section we will present a summary of main findings and highlight areas that need further research, focusing on environmental enrichment, reduction of stocking density, increased age

at weaning, neonatal socialization and family rearing, the prevention and treatment of lameness, automatic feeding and supply of fibre for sows and biosecurity, prevention and eradication of diseases in pig herds.

2.6.1 Using environmental enrichment, increasing space and reducing stocking density

Environmental enrichment is a way to improve the environment by making it more attractive to pigs (NEWBERRY; WOOD-GUSH, 1985). It allows pigs to express their highly motivated exploratory behaviour, reducing the risk SCOLLO of tail and ear bites and also the stress of grouping in piglets (MARCHANT-FORDE, 2009; SCOLLO et al., 2013). Prioritizing the supply of manipulable materials is efficient way to reduce the incidence of tail biting (VALROS, 2018). Some studies showed that providing chewable materials such as wood and rubber early in life reduced the incidence of tail-biting behaviour (CHOU et al., 2020; TELKÄNRANTA et al., 2014). Different studies have also shown the beneficial effects of environmental enrichment on pig behaviour and positive affective states at all stages of rearing. For example, enriching the environment of pigs weaned with straw, toys and manipulable materials can reduce the incidence of redirected oral behaviours (KO et al., 2020; LIDFORS et al., 2020). Also, the use of fresh materials, such as peat, led to an increase in the positive affective states of pigs, evidenced by the increase in exploration and play and in the reduction of aversive behaviours, such as aggression and tail and ear bites (OCEPEK et al. 2020). The enrichment of the maternity housing with chewable materials stimulated the exploratory behaviour of the piglets and increased the frequency of non-painful contact of the piglets with the udder, reducing the stress of lactating sows (SWAN et al., 2021).

To provide adequate exploratory and manipulative activities it is important that the materials are available permanently and that they do not compromise the health of the pigs (VAN DE WEERD; DAY, 2009). It is important to provide materials to pigs that allow satisfactory interaction. Straw is considered an enrichment of choice for pigs because, added to offers advantages regarding hygiene, environment, labour and economics (TUYTTENS, 2005). Choosing the materials according to pigs' preferences helps maintain interest in the objects over time. For example, weaned piglets have a preference for exploring ingestible, chewable, odorous, deformable and destructible materials (VAN DE WEERD; DAY, 2009), rather than interacting with objects such as tires and chains (OCEPEK et al. 2020). To minimize problems

with manure management on farms, manipulable materials may be provided in racks (WALLGREN; GUNNARSSON, 2021).

Sows housed in gestation groups also benefit from environmental enrichment. Providing sows with access to straw for building nests during pregnancy in free parturition systems reduced stress and the expression of abnormal behaviours (ZHANG et al., 2020). Fibre increases the volume and absorb water, which stimulates the mechanical receptors of the stomach and decreases gastric emptying, providing satiety (D´EATH et al., 2018). Providing more space and straw can reduce the incidence of gastric ulcerations and agonistic interactions between sows (D´EATH et al., 2018; HERSKIN et al., 2016). A recent study suggested that, besides reducing the stress of sows, environmental enrichment at the end of gestation may affect the offspring, positively influencing the activity of the HPA axis and reducing abnormal behaviours such as aggressiveness and belly-nosing (TATEMOTO et al. 2019).

High pig stocking density, typically associated with older pig farm facilities, not designed to house litters of hyper-prolific sows, may increase the incidence of behavioural problems and inappropriate social interactions (BÜTTNER et al., 2015). Increasing post weaning space allowance an improve growth, health and behaviour (PLUSKE et al., 2019) as well as reduce tail biting (VALROS, 2018). Grower pigs housed with a space of 1.2 m²/pig showed fewer skin lesions, less manure on the body and lower body temperature compared to pigs with higher stocking density (FU et al., 2016). Combining greater space with environmental enrichment using toys improved weight gain and feed conversion of growing pigs and reduced the frequency of aggressive interactions (LI et al., 2021).

Providing space for locomotion can be beneficial for the behaviour of pigs and the health of the locomotor system. For example, Etterlin et al. (2015) found a lower incidence of osteochondrosis in free-range pigs compared to confined pigs. The possibility of exercising and exploring the environment is related to muscle and joint strengthening, which is beneficial to the health of the pigs (PIETROSEMOLI; TANG, 2020). Although outdoor systems can be challenging in terms of biosecurity and postpartum management (DELSART et al., 2020), animal welfare benefits must be considered. In outdoor settings, pigs have the opportunity to explore a rich environment, perform behaviours such as foraging and exploration and stay in places with pleasant climatic conditions, as long as these environments are well managed (PIETROSEMOLI; TANG, 2020). Furthermore, in these systems pigs are less affected by

respiratory infections than pigs confined (DELSART et al., 2020), which can contribute to the reduction of AMU.

Further studies should be directed to developing forms of housing in which pigs are able to move and explore, and also to feel protected from threats. Building barriers and hiding places can also be an alternative to reduce agonistic interactions and stress (BULENS et al., 2017). Providing hiding opportunities can protect newly housed sows from aggressive interactions with resident sows (BENCH et al., 2013a)

2.6.2 Providing opportunities for neonatal socialization and weaning at later ages

An alternative to minimize the stress of agonistic interactions during the weaning phase is the socialization of piglets during lactation (D'EATH 2005; LANGE et al. 2020; PRUNIER et al. 2020). Pre-weaning socialization, associated with environmental enrichment can improve the piglets' adaptation to weaning, stimulating exploratory behaviour and decreasing aggression, even in groups of unfamiliar piglets (KO et al., 2020).

Weaning piglets later has positive impacts on piglet welfare. For example, later-weaned piglets have a greater diversity and abundance of bacterial microflora in the gastrointestinal-tract (MASSACCI et al., 2020), which may help reduce the incidence of diarrhoea and the use of antibiotics in this critical phase. Later weaning also has advantages in relation to the piglets' affective states, as older weaned piglets show lower incidence of post-weaning belly nosing (FACCIN et al., 2020; PLUSKE et al., 2019). Maintaining the social group after weaning can improve piglet welfare. Previously socialized piglets are better adapted to the post-weaning environment, reduce post weaning agonistic interactions and resulting lesions, are more relaxed and play more with each other (CAMERLINK et al., 2018; MORGAN et al., 2014; SALAZAR et al., 2018).

2.6.3 Providing positive emotional states and positive human-animal interactions

Providing pleasant environments, promoting positive human-animal interactions and housing and management that allow the expression of species-specific behaviours can promote positive emotional states, reduce stress and boost the immunological system. Affiliate behaviours such as allogrooming, or social nosing in the case of pigs (BOISSY et al., 2007) and play (HELD; ŠPINKA, 2011) are rewarding to animals. These behaviours are associated with long-term and contagious states of relaxation and pleasure among other animals in the herd

(HELD; ŠPINKA, 2011). The expression of pleasurable behaviours is therefore a valuable indicator of welfare (BOISSY et al., 2007; BRACKE; HOPSTER, 2006; MELLOR et al., 2020).

Positive human-animal interactions can include friendly human presence, contact and tactile stimuli (scratching or caressing), providing food and objects for interaction, positive reinforcements and peaceful and pleasant routines with animals (RAULT et al., 2020). Upon receiving pleasurable stimuli, pigs increase serum levels of oxytocin and vasopressin (BOISSY et al., 2007; LÜRZEL et al., 2020) that trigger the release of dopamine. Prolonged gentle handling has beneficial effects on reducing stress and anxiety in pigs, as well as on performance and carcass characteristics (WANG et al., 2020). Pregnant and lactating sows that received positive tactile stimuli associated with music had a higher number of piglets weaned (DE MEYER et al., 2020) and piglets that received positive handling early became calmer, less reactive and gained more weight (OLIVEIRA et al., 2019) In contrast, weaned piglets avoid aversive keepers and recognize them several weeks after weaning (SOMMAVILLA et al. 2011).

The reactions expressed by pigs when in contact with humans are also important indicators of animal welfare (RAULT et al., 2020). Pigs are able to become familiar with routines and keepers and identify those who handle them carefully or aggressively. Gentle handling of animals should be central for pig productions systems that high advocate animal welfare standards (TARAZONA et al. 2019). Providing pigs with calm and pleasant routines keeps the working environment peaceful and healthy for humans and animals (HEMSWORTH; COLEMAN, 2011). Trained workers demonstrate more positive interactions and attitudes towards livestock than inexperienced employees (CEBALLOS et al., 2018). When they demonstrate that they are trained, motivated and committed to the welfare of the animals, stock people will exercise their duties properly and avoid situations that may risk and cause accidents to the animals and to themselves (VALADEZ-NORIEGA et al., 2018). Pig farmers with positive attitudes towards pigs showed more empathy for animals and pleasure in working (POL et al., 2021). Finally, positive human-animal interactions are essential to ensure the welfare and quality of life of pigs on farms and maintain the social license of the pig industry as well as to reduce the use of antibiotics in farms (BJÖRKMAN et al., 2021).

2.7 RELATIONSHIP BETWEEN ANIMAL WELFARE AND USE OF ANTIBIOTICS

The management factors that cause suffering in the pigs analysed here are indirect examples of ways poor welfare conditions on farms are a source of stress, which can facilitate the occurrence of diseases that are commonly treated with antibiotics. There is a scarcity of scientific literature reporting a direct causal relationship between distress in pigs and AMU. However, some findings are relevant starting points for the discussion on the prudent use of antibiotics and the promotion of the quality of life for pigs. Some studies have shown that, with the adoption of changes in biosecurity, animal care and management it is possible to reduce AMU in pig farms without compromising health or performance (COLLINEAU et al., 2017; DIANA et al., 2019; RAASCH et al., 2020; ROJO-GIMENO et al., 2016).

Although the clinical importance of antibiotics is recognized, several studies have reported the deleterious effects of inadequate exposure to antibiotics in different animal species (BECATTINI et al., 2016; MIYOSHI et al., 2017). Newborn rats whose mothers received peri-partum antibiotics had gut microflora dysbiosis, immune dysfunction and intestinal inflammation that persisted throughout their adult lives (MIYOSHI et al., 2017). Similar findings have been reported in humans (BECATTINI et al., 2016; FORGIE et al., 2019) and pigs (FOUHSE et al., 2019) treated with amoxicillin during early life. In a study using pigs as models for human babies, the early treatment of piglets with amoxicillin promoted, in addition to changes in the intestinal microbiota, pancreatic changes that compromised glucose metabolism (LI et al., 2017).

The use of antibiotics has also been associated with some neurobehavioral problems. One study found greater aggressiveness and frequency of agonistic interactions in growing pigs that constantly received prophylactic antibiotics compared to those that did not receive the medication (DIANA et al. 2017). The authors were unable to determine whether the aggressiveness was related to a greater voracity of the medicated pigs and to disputes over food or to disturbances of the intestinal microflora caused by antibiotics (DIANA et al. 2017). Studies with other species have also shown changes in animals suggested as consequences of early or frequent use of antibiotics. For example, prolonged antibiotic supply was linked to increased anxiety and depression in rats, changes in serum leptin levels and in blood-brain barrier permeability (GLOVER et al., 2021). The early exposure of antibiotics via maternal milk to newborn rats generated anxiety, sociability and cognitive difficulties (O'CONNOR et

al., 2021). These findings are valuable indications that there is a need to explore and better understand the adverse effects caused by antibiotics in animals and humans.

We also emphasize the importance of seeking greater evidence related to risk factors for the use of antibiotics, as well as the harmful effects of their misuse. We identified these two points as important knowledge gaps for the development of new research in animal welfare and health.

2.8 CONCLUSIONS

Among the many challenges that need to be overcame for effectively reducing the use of antibiotics on intensive pig production farms, it is crucial reducing stressors that facilitate illnesses in pig herds. This review highlighted the main ways pig rearing in intensive systems impinge upon homeostasis and can increase the animals' susceptibility to diseases. This includes some factors inherent to animals (such as selection for rapid growth and hyper prolificity); factors inherent to the environment and housing management (such as high stocking density, social isolation and barren environments), and factors inherent to animal management (such as sow and piglet diets, early weaning, painful practices, transport, and quality of the relationship human-animal). In each of these examples, we pointed out that there are alternatives to prevent or reduce stress, even if in many cases it is necessary to invest more in research, such as sow maternity systems, training of personnel and other aspects related to the welfare of breeding males that were not addressed in this review.

Public opinion must be seen as an important force for change in production systems. Restrictive breeding systems and painful management (HÖTZEL et al. 2020) are less and less accepted by the public (HÖTZEL et al., 2020; VANDRESEN; HÖTZEL, 2021; YUNES et al., 2017), which seeks alternatives focused on free systems and naturalness (SATO et al. 2017). However, we also need to understand the causes behind the relatively low adoption by the industry of several of the alternatives that have been developed in recent decades (ALBERNAZ-GONÇALVES et al. 2021b; MOLNÁR; FRASER, 2020). In some cases, there may be a need for user involvement in the early stages of the research and regulation development.

Many alternatives proposed as solutions to improve animal welfare do not satisfy the wishes of farmers (ALBERNAZ-GONÇALVES et al. 2021b) or consumers (YUNES et al., 2018). In some cases, there may be a need to make changes to the users of the innovations.

Some practices are used successfully in some countries, but not in others. Some examples are the use of beds or other enrichments, immune castration, the rearing of whole pigs, or with intact tails, of pregnant sows in group housing systems, family systems and later weaning. This poses a challenge to the production system, as it demonstrates that the argument that these practices are not applicable in the field is not sustained in practice.

The adoption of good management practices that respect the characteristics of the pigs is essential to meet the international call for prudent use of antibiotics. We have shown indirect evidence that happy, unstressed pigs are more immune competent, more capable of naturally defending themselves from environmental pathogens, and therefore less dependent on preventive antibiotics. Sustainable pig production systems must provide healthier meat to consumers and meet the demands of consumers and urban citizens who are concerned with the origin of the food (CLARK et al., 2016). The way pigs are raised in intensive systems is incompatible with the OIE's definition of animal welfare, which states that the physical and mental health of animals involves positive affective states (OIE, 2019b). Phasing out widely established practices that cause pain and stress and preclude positive emotional states to pigs may address simultaneously two demands from society: improving the welfare of pigs and reducing the use of antibiotics. Within the premises of One Welfare, with the improvement of the quality of life for pigs, we can improve the well-being of consumers and farmers themselves.

3.EXPLORING FARMERS' REASONS FOR ANTIBIOTIC USE AND MISUSE IN PIG FARMS IN BRAZIL

R. Albernaz-Gonçalves, G. Olmos, M.J. Hötzel

3.1 ABSTRACT

Stressful management that makes farmed pigs susceptible to infections is associated with high antibiotic use (AMU) and resistance (AMR). Pig farmers are key stakeholders to sup-port the international agenda pushing AMU restrictions. We interviewed 58 pig farmers on AMU/AMR, biosecurity, veterinary assistance, disease prevention and treatment, aiming to understand practices and attitudes towards the AMU/AMR problem. Farmers described a reliance on antibiotics to prevent and treat disease while neglecting biosecurity measures. We identified inappropriate AMU practices (high use of broad-spectrum antibiotics, incorrect dosage or treatment length) and unrestricted access to antibiotics, which encouraged imprudent AMU. Nevertheless, most farmers considered this AMU legitimate to guarantee herd productivity and showed unpreparedness and resistance to changing AMU practices, perceiving limitations (economic, sanitary and inspection) more easily than alternatives to reduce AMU. Agroindustries and foreign markets were mentioned, and internal consumers dismissed as potential motivators for behavioural changes. Importantly, farmers' economic, technical and social factors may limit their autonomy to change practices. We conclude that the observed distancing of pig farmers from the AMU/AMR problem limits the efficiency of policies aiming for a prudent AMU. Our study indicates a need for education, training and behaviour change nudging that should include other stakeholders beyond farmers.

Keywords: antimicrobial; AMU; AMR; attitudes; livestock; prudent use of antibiotics; swine

3.2 INTRODUCTION

The definition of antimicrobial resistance (AMR) proposed by the Global Action Plan (WHO, 2015) refers to the resistance acquired by several microorganisms (bacteria, fungi, viruses and parasites) to antimicrobials. This concept covers a range of drugs; however, the focus of the present study is on antibiotics, due to the high level of use and importance that these drugs have in the pig production chain (BARTON, 2014; VAN BOECKEL et al., 2015). The antibiotic use (AMU)/AMR problem is often considered a health problem; yet, building

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evidence indicates that AMR is an evolutionary challenge accelerated by social, cultural and economic factors that lead to the misuse, overuse and abuse of these life-saving medicines (MINSSEN et al., 2020). Scientific evidence links the use of antibiotics in livestock with the risk of transmission of antibiotic-resistant bacteria to humans (VAN BOECKEL et al., 2017; WOOLHOUSE et al., 2015) mainly due to the use of antibiotics in low doses in the diet of animals (KIRCHHELLE, 2018a; VAN BOECKEL et al., 2017). AMR transmission can occur through direct contact with contaminated people, animals and food, or through the environment, via animal waste containing resistant bacteria that may contaminate soil and water (HE et al., 2020; VAN BOECKEL et al., 2015; WOOLHOUSE et al., 2015). Antibiotic residues can also induce the selection of resistant bacteria in the environment. For instance, the presence of antibiotic residues and genes of resistant bacteria has been detected in surface waters supplying urban areas in China and the Netherlands (HONG et al., 2020; SABRI et al., 2020). Irrigation water and manure used for fertilization may also contain residues of antibiotics that will be absorbed by the soil and plants (PIÑA et al., 2020). This complex and intricate relationship between human behavior and human, animal and environmental health strengthens the need for multidisciplinary approaches to tackle AMR.

Although there is an international mobilization to encourage measures of prudent use of antibiotics in livestock, in low- and middle-income countries sales of veterinary antibiotics are unregulated (VAN BOECKEL et al., 2019). Several studies in these countries show a relationship of antibiotic dependence, mainly in pig farming (DYAR et al., 2020; LEKAGUL et al., 2020). The WHO, FAO and OIE consider AMR a global health emergency, which has led to the development of policies aiming to reduce the use of antibiotics in several countries (BVA, 2019; FAO; DVFA, 2019; WHO, 2015). This stance can force countries that rely on export livestock products to conform to international recommendations for prudent use of antibiotics. Brazil is the fourth largest producer of pork in the world and a signatory to the OIE, and its economy is highly de-pendent on the export of its agricultural products (VON

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KEYSERLINGK; HÖTZEL, 2015). The PAN-BR is a plan put forward by the Brazilian Health Ministry together with other government entities to adapt to the practices of rational use of antibiotics in the coming years (BRASIL, 2018). Pressure from foreign markets may require Brazilian health agencies and the animal production chain to rapidly adapt to the international scenario of restriction of the use of antibiotics (WORLD BANK GROUP, 2019). These changes require rethinking the current production systems that rely on high antibiotic use.

Many Brazilian pig farmers are subordinated to industrial groups that establish rules for pig rearing. These farmers, as well as independent pig farmers, will be directly responsible for implementing measures to cope with the restriction of the use of antibiotics. Thus, it is important to understand the knowledge and opinions of this group, as they are mediators and guardians of animal health, and likely the most affected by the burden of change. Qualitative social research brings a different perspective to the use of antibiotics that can help us to understand the attitudes of farmers in relation to this topic, especially about how they perceive antibiotics in their routine and their expectations in relation to a scenario of change (COYNE et al., 2019; KRAMER et al., 2017). There is a need to understand how Brazilian pig farmers feel about this problem, if they see the need to change and, if so, whether they are prepared to modify their practices in order to reduce the use of antibiotics. Thus, the aim of this study was to explore the knowledge, attitudes and practices of pig farmers regarding the use of antibiotics in pig farming, as well as regarding bacterial resistance to antibiotics.

3.3 MATERIALS AND METHODS

This study, conducted by the Applied Ethology Laboratory of the Federal University of Santa Catarina (LETA-UFSC), is part of the research project entitled “Knowledge and attitudes of Santa Catarina’s pig industry on antibiotics, bacterial resistance and animal welfare”. Thus, some details of the methodology are similar to those presented ALBERNAZ-GONÇALVES; et al. (2021). This particular study followed a qualitative approach, using in-

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depth semi-structured interviews to understand pig farmers' knowledge and attitudes about antimicrobial resistance (AMR) and prudent use of antibiotics.

3.3.1 Study Location

Pig farming is one of the main Brazilian livestock and agribusiness activities. Brazil holds the fourth position as a global pork producer and exporter (FAO 2020). Santa Catarina (SC) is the Brazilian state with the largest production in Brazil, housing 25% of the sows (SEBRAE; ABCS, 2016). Braço do Norte, located between 28° 16' 30" S and 49° 09' 56" W, is a municipality belonging to the micro-region Tubarão, which is the second-largest pork-producing region in Santa Catarina. Tubarão has 19 municipalities and around 1500 registered pig production units, housing a total of 100,000 sows. This site was chosen for the study because it presents intensive pig farming systems that are relatively diverse regarding labor type, herd size, production types and production models (Table 1). Pig production in the southern region of Brazil is characterized by specialized production segregated into several breeding sites and some full-cycle farms. Most (~70%) of the farms in the studied region are considered medium-sized, i.e., house between 300 and 1000 housed pigs; the predominant production models are integrated pig farmers (62%), cooperatives (26%) and independent producers (12%) (SEBRAE; ABCS, 2016). Braço do Norte specializes in the production of weaned piglets for fattening, but it also has full-cycle farms that sell finished pigs for slaughter in small local slaughterhouses.

Table 1. Demographic characterization of the visited farms (n = 58).

Farm Type	Total n (%)
Farrow-to-finish	19 (33)
Breeding farms	26 (45)
Growing farms	4 (7)
Fattening farms	9 (15)
Herd size (number/herd)	
≤100 sows or finished pigs	7 (12)
101–500 sows or finished pigs	28 (48)
501–1000 sows or finished pigs	13 (22)

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>1000 sows or finished pigs	10 (17)
Other farm activities	
Pig farming only	7 (12)
Dairy cattle	42 (72)
Aquaculture	10 (17)
Beef cattle	7 (12)
Other	1 (2)
Labor type	
Family and hired	28 (48)
Family	25 (43)
Hired	5 (9)

Source: Author

3.3.2 Participants' Recruitment

The interviews were done face-to-face between January and February 2019; all interviews were carried out in the Brazilian Portuguese language by the same person (R.A.-G). Before beginning the interview, the participant was given and read a free informed consent form, which contained all the information relevant to the interview. The audio recording and interview process started only after the interviewee(s) understood and signed the consent form. Participants were invited to ask questions, interrupt the interview or withdraw from the study at any time. The average duration of the interviews was 34 min per interview (between 12 min and 1 h 20 min).

The first participants were recruited through a network of contacts of the first author (former students resident in the region). These informants indicated potentially interested farmers, of which 12 accepted to participate. Other farmers were identified using a non-probabilistic snowball sampling method, which is a method indicated for accessing information

from difficult-to-reach groups (ROLLER; LAVRAKAS, 2015). Difficulties in accessing farmers included an outdated list of breeders' associations, distance from urban centres and lack of Internet and telephone access. Initial contact with producers was done over the phone or on a first a visit to the farm to make the invitation and arrange the interview.

From a total of 63 visits, 58 interviews were completed. The interviews were conducted in two stages: first, we interviewed 40 farmers, analysed the responses obtained and returned to the study region to carry out more interviews; after the second analysis of another 23 interviews, as we did not identify new elements in the participants' responses, we considered that the number of interviews ensured good data saturation and an in-depth, diverse and rich report on the topic. The sample size for qualitative research de-pends on the diversity of the population studied and the amount and wealth of data collected from each participant (BRAUN et al., 2019; BRAUN; CLARKE, 2006a). The participants in this study provided a rich sample of data as they represented a plurality of production contexts and demographic data (Tables 1 and 2).

Table 2. Demographic data of the pig farmers (n = 58).

Gender	***n***	**%**
Male (M)	45	76
Female (F)	13	24
Work experience		
<5 years	3	5
6–10 years	5	9
11–15 years	11	19
16–20 years	5	9
>20 years	34	58
Education		
Elementary school	15 (10M, 5F)	26
High school	35 (30M, 5F)	60
Higher education	8 (5M, 3F)	14

Source: Author (2021)

3.3.3 Interview Script

The interview script contained semi-structured and open-ended questions (Table S1, S2 and S3). The interview was divided into five sections, which corresponded to 1) socio-demographic issues, 2) biosecurity practices, 3) forms of disease prevention and control, 4) means of diagnosis, treatment and technical assistance and 5) knowledge and attitudes about bacterial resistance to antibiotics. At the end of the interviews, participants were presented with a hypothetical scenario of prudent use of antibiotics and were asked two questions: “If in the future the use of antibiotics as growth promoters and prophylactics were not allowed, and the use of parenteral antibiotics controlled, what would be the impacts of this scenario for pig farming in Brazil?; What measures would be necessary to reduce the use of antibiotics in pig farming?”.

3.3.4 Data Analysis

To analyse the material obtained in the interviews, we used an inductive (reflexive) thematic analysis approach, following the analysis proposed by BRAUN and CLARKE (2006) and BRAUN et al., (2019). This type of investigation is not associated with any specific theoretical framework and provides a flexible and varied approach beyond the researcher's insights or expectations. In order to define and code the themes of the inductive thematic analysis, the authors made an exhaustive reading of the transcripts to become familiarized with the data. In the inductive approach, the analytical process starts from the data, working “bottom-up” and, therefore, is based on the responses of the interviewees to minimize bias. Each theme was refined through interactive discussion between the three authors, and names (titles) and clear definitions for each theme were created. The analysis was carried out with the aid of the NVivo qualitative data management program (version 11, 2015; QSR International Pty Ltd., Doncaster, VIC, Australia). The selected excerpts representing the themes were translated into English by MJH and revised by GO.

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Quotes are displayed in Appendix 1 and are cited in the Results section by farmer number and order of appearance (e.g., F30a refers to the first excerpt from the interview with Farmer 30; F3b is the second excerpt quoted from the interview with Farmer 3).

3.4 RESULTS

3.4.1 Demographic Data and Characterization of Farms

Demographic and farm data are shown in Tables 1 and 2. The visited farms had between 50 and 1200 sows or finishing pigs, including full-cycle (or farrow-to-finish) farms, piglet-producing units (or breeding farms), growers and fattening units. In general, the interviewees considered themselves as experienced pig producers, with 82% of the participants stating having more than 10 years of experience in the industry.

Some of the farmers complemented their income from pig farming with other work/activities, with dairy cattle present in most farms. Family members performed the farm labor but some also hired staff to aid on the farm. In most of the visited farms, a man was responsible for running the farm, although in these farms women were also included in the routine of the farms, mainly in the care of dairy cattle.

3.4.2 Pig Production Models and Purchase of Antibiotics

The farmers that participated in this study belonged to three distinct production models: some worked independently (n = 36) and some were associated with one of the three integrators (n = 15), or one of the two cooperatives (n = 7) involved in pig production in the area. Integrated and cooperated farmers met criteria established by the Ministry of Agriculture, Livestock and Supply (MAPA) to sell their products nationally and internationally. Independent farmers worked with the municipal or state inspected slaughterhouses, which supplied the Brazilian domestic market. In the piglet-producing units, the piglets were weaned and transported to fattening farms located in western Santa Catarina.

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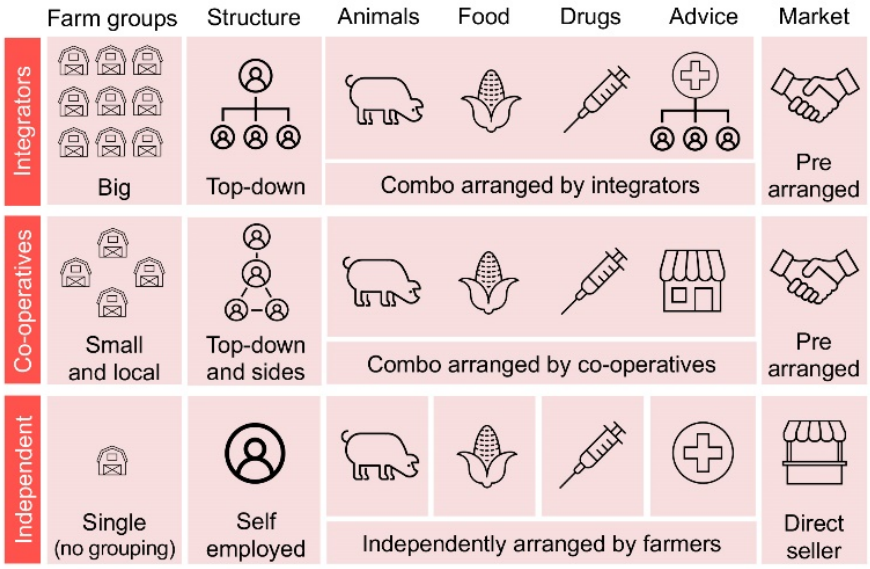
Many practices were shared across farmers regardless of the production model; however, the way farmers acquired inputs and sold their products differed according to the production model (see Figure 1). In summary, all farmers linked to integrators had a pre-agreement with agroindustries whereby the company provided basic inputs (pigs, feed, medicines) and technical assistance, while the farmer was responsible for the infrastructure, labour and supply of animals for slaughter. Integrators are big companies that have farmers at their command; on the other hand, cooperatives are organizations formed by groups of associated farmers, which work in a similar way to the integration model but at a local level. Independent farmers had no contractual ties to specific agroindustries or cooperatives, and therefore were not subject to the same work and organization rules as the other groups and were responsible for purchasing inputs and selling their animals (Figure 1).

Figure 2. Schematic representation of pig production models in Brazil.



Source: Author

Most of the independent farmers (67%) produced their animal feed on their farms from grains they produced themselves and some additional external inputs (e.g., vitamin and mineral

ingredients) purchased from local shops or through vendors. When they considered it necessary to add antibiotics to the feed for group treatment or for prophylactic use, independent farmers bought the powdered antibiotics for mixing in feed. It is important to note that these farmers were not complying with the norms of IN65/2012/MAPA (F30a). However, their reports indicated that they were not sufficiently informed about these regulations and that they did not consider this practice incorrect. The supply of antibiotics for feed by shops or through vendors also breached the rules and indicates a lack of inspection by health agencies in commercial establishments. Independent farmers also bought injectable antibiotics from local agricultural shops (53%) or through vendors of nutritional inputs (45%). Farmers who received vendors on their farm informed us that they placed orders via cell phone messages. According to these farmers, there was no difficulty in acquiring antibiotics (F57a) and no participant reported being required to have a veterinary prescription for the purchase of medications at shops or from vendors.

The integrated farmers received from the company, together with the feed, a package with all veterinary antibiotics and a list of medications recommended for each situation. In this list, signed and stamped by a responsible veterinarian, there was a list of clinical signs, respective probable diseases and recommended medications (antibiotics, anticoccidials, anti-inflammatories and disinfectants), with the concentrations of each active ingredient and recommended dose. As a company rule, farmers from integrators could not purchase veterinary medicines on their own. The companies informed their members when antibiotics were included in their feed, according to the recommendations of field technicians and veterinarians (F50a). Farmers from cooperatives also received lists of medications, or received medications and feed, medicated or not, from the cooperative; however, they were also allowed to purchase these inputs at shops.

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3.4.3 Level of Adoption of Biosecurity Practices on Farms

Biosecurity practices adopted on the farms, as described by the farmers, are shown in Table 3. Following biosecurity protocols, the presence of the research team during the visits was restricted to the external environments of the farms. Although unauthorized persons were not allowed to enter the farms, we did not observe any physical barriers (bars, screens, green barriers) or wheel dip. The information we obtained about vaccination was inaccurate, partly because of the confusion that many farmers had between injectable antibiotics and vaccines (F3a), so we did not consider data on that topic.

Table 3. Biosecurity practices adopted by the farms visited.

Biosecurity Practices	**Frequency *n* (%)**			
	Never	**Rarely**	**Sometimes**	**Always**
Chlorine in drinking water	41 (71)	4 (6)	1 (2)	12 (21)
Rodent control	12 (21)	7 (12)	15 (26)	24 (41)
Visitor control	47 (81)	1 (2)	0	10 (17)
Vehicle control	48 (83)			10 (17)
	Never	<7 days	7–14 days	>14 days
Sanitary periods	17 (30)	24 (41)	14 (24)	3 (5)

Source: Author

Few farmers cited basic biosecurity practices such as treatment of drinking water with chlorine, or control of rats, visitors and vehicles (F1a; F2a). Few farms kept the farm facilities empty for longer than 7 days after cleaning and disinfection ahead of initiating a new productive cycle. Furthermore, none had quarantine protocols for the introduction of new animals to the herd. Replacement gilts were housed in pens separated from the older sows, but shared the same environment with sows and breeding males.

3.4.4 "Antibiotic Shocks" and the Trivialization of Antibiotic Therapy

Farmers used antibiotics for therapeutic and prophylactic treatments and as growth promoting additives. All farmers mentioned the use of antibiotics as the main way to prevent

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infections in pigs and considered antibiotics indispensable in pig farming (F3b; F19a). Only 19% of the farmers acknowledged using antibiotics as growth promoters when they were not using them for prophylactic treatments, and 29% did not know if their diets contained growth promoters.

In the farrow-to-finish and breeding farms, 85% of farmers used what they called "antibiotic shocks" to prevent genitourinary infections in the sows (Table 4). They alternated different antibiotics for the sows in each cycle of medication (F2b; F57b). Farmers rarely mentioned preventive measures for breeding sows that did not involve antibiotics; for example, only 7% mentioned vaccinations and 5% used organic acids and prebiotics. Sows that showed evident symptoms of untreatable/uncontrollable infections were culled (F15a).

Table 4. Infection prevention and control measures adopted on breeding farms.

Control of Infections in Sows[*1]	**Total *n* (%)**
Antibiotic in feed (antibiotic shock) every 6 months	19 (42)
Treatment in cases of present infection	7 (16)
Antibiotic in feed (antibiotic shock) every 4 months	6 (13)
Antibiotic in feed (antibiotic shock) every 3 months	4 (9)
Agro-industry control	4 (9)
Antibiotic in feed every 2 months	3 (7)
Antibiotic in feed for month	2 (4)
Control of infections in newborn piglets[*1, *2]	
Oral anticoccidial	26 (58)
Injectable antibiotic	20 (44)
Oral antibiotic	8 (18)
Oral prebiotic	2 (4)
Control of infections in weaning pigs [*3]	
Continued antibiotic use in feed	13 (41)
Antibiotic shock every feed change	12 (38)
Injectable antibiotic before weaning	4 (13)
Others	3 (9)

[*1] % based on the number of farrow-to-finish and breeding farms (n = 45); [*2] these items were cited more than once by the same participants, so the sum of citations is higher than the number of respondents; [*3] % based on the number of farrow-to-finish, growing and fattening farms (n = 32).

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Weaned piglets also received prophylactic antibiotics continuously in the diet or as "antibiotic shocks" (Table 4). All farmers described alternating antibiotic groups, that is, with each feed batch, the piglets received a different antibiotic. For this reason, a piglet could have contact with six or more antibiotic groups between 28 and 70 days of life (F17a; F19b). The groups of antibiotics most cited were aminopenicillins, tetracyclines and amphenicols for use in diets; quinolones, aminopecillins and macrolides for injectable use (Table 5). Farmers used injectable antibiotics to prevent infections in newborn piglets, be-fore weaning the piglets and when replacement gilts were moved to the sows' building (F41a; F60a; F3c; F18a; F35a).

Table 5. Most cited antibiotic groups by pig farmers.

	Antibiotic Groups	*n* (%)		Antibiotic Groups	*n* (%)
Antibiotics in Feed	Aminopenicillins	24 (41)	Injectable Antibiotics*[1]	Quinolones	36 (62)
	Tetracyclines	23 (40)		Aminopenicillins	34 (59)
	Amphenicols	19 (33)		Macrolides	19 (33)
	Pleuromutilins	13 (22)		Others	6 (10)
	Others	23 (40)			

*[1] These items were cited more than once by the same participants, so the sum of citations is higher than the number of farmers. The percentages were calculated based on the number of participants (*n* = 58).

Source: Author

Some farmers claimed to control piglet diarrhoea with antibiotics in the feed of lactating sows (F61a). Farmers also used antibiotics to treat individual cases of neonatal pneumonia and diarrhoea. When more than one pig in the group had symptoms, the entire group was given therapeutic doses of antibiotics via feed or water.

Some statements suggest that the pigs were exposed for long periods to large amounts of antibiotics (F18b). Farmers expressed a social conformity in the use of antibiotics as a preventive strategy. Yet, the ways of conveying their behavior indicate that they downplayed an action that they found unusual themselves (F30b). This was also identified in the constant use of the term "antibiotic shocks" to refer to the strategic use of antibiotics in pig diets for

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preventive purposes, and reference to antibiotic therapy as a simple and routine practice (F51a; F46a).

Although 72% considered the cost of antibiotics to be high (F18c; F35b), farmers said that spending money on antibiotics was necessary to avoid the risk of losses due to dis-ease or increased mortality (F42a; F31a). In other words, in the view of these farmers, antibiotics were a "necessary evil".

3.4.5 Disease Diagnosis, Drug Prescription and Farmer/Veterinarian Assistance

All farmers received some type of veterinary technical assistance, through nutrition input companies, integrators or cooperatives (Table 6). Some nutrition or pharmaceutical companies provided free assistance to farmers who purchased their products. According to the farmers, in most cases, field technicians or veterinarians visited the farms weekly or only in emergencies. Integrated farmers linked to cooperatives had periodic visits, while independent farmers relied on visits by vendors or called veterinarians, which for some limited access to qualified information (F57c).

Table 6. Information on feed purchase and technical assistance.

How do you get the feed?	**Total *n* (%)**
Make on the farm	39 (67)
Is provided by the industry	17 (30)
Purchase	2 (3)
Where do you buy veterinary antibiotics?	
In agricultural stores	31 (53)
The agribusiness sells me the drugs	15 (26)
The agribusiness gives me the medicines	7 (12)
From feed supply seller	5 (9)
Who do you receive technical assistance from?	
Veterinary nutrition supply company	26 (45)
Integration or cooperative veterinarian	22 (38)
Private veterinarian	5 (9)
Veterinarian is part of the family	3 (5)
Agricultural technician at the agricultural store	2 (3)
Frequency of visits by veterinarian	
Weekly	20 (34)
Emergencies	19 (33)

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Monthly	11 (19)
Biweekly	7 (12)
Daily	1 (2)

*The percentages were calculated based on the number of participants (n = 58).
Source: Author

Most farmers claimed to be able to identify diseases and choose treatments according to their own experience, as show in Table 7. They decided on the doses of antibiotics following recommendations from the label or in the lists provided by the companies. We observed some flaws in the use of antibiotics, such as the choice of inappropriate active ingredients, incorrect use of doses and insufficient treatment time; farmers also used antibiotics to treat viral infections, indicating that they had difficulty in distinguishing bacterial from viral infections (F61b; F41b; F60b; F35c; F18d). Few farmers mentioned using antibiotic sensitivity tests, and this only happened in specific cases when farmers were facing health challenges that were difficult to control on their farms (F59a).

Table 7. Information on the most common diseases, means of diagnosis and treatment criteria described by the pig farmers.

Most Frequent Diseases[*1]	**Total *n* (%)**

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Enteric diseases	40 (69)
Respiratory diseases	31 (53)
Encephalitis	10 (17)
Others	5 (9)
Do not know	4 (7)
Diagnosis of diseases	
Just from my experience	44 (76)
Veterinarian guidance	12 (21)
Agricultural technician guidance	2 (3)
Antibiotic dose	
Follow label directions	39 (67)
Follow the vet's guidance	18 (31)
Follow the guidance of the agricultural store	1 (2)
Treatment time[*1]	
Veterinarian guidance	16 (28)
Follow label directions	16 (28)
1 to 3 days of treatment	15 (26)
Long-acting antibiotic (single dose)	11 (16)

*[1] These items were cited more than once by the same participants, so the sum of citations is higher than the number of farmers. The percentages were calculated based on the number of participants (n = 58).

Source: Author

3.4.6 AMR expressed as a failure of the antibiotics, not human actions

Forty-five percent of farmers did not know if there were similarities between antibiotics for human and veterinary use, while 26% believed there were some similarities, and 21% said they were the same drugs (F35d). Some of them believed that even if antibiotics were shared between species there would be no risk to consumers, as long as the withdrawal period before slaughter was respected. Farmers defined AMR as the failure of antibiotics to control disease (F1a; F14a). As contributing factors to the development of AMR, farmers mentioned the continued use of the same active ingredients (74%), incorrect dosage (14%), unnecessary use of antibiotics (5%) and incorrect treatment time (5%). Some farmers associated AMR with low immunity of pigs (F58a; F37a).

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3.4.7 Farmers' Perceptions of Consumers' Beliefs Regarding AMU

About half of the interviewed farmers (53%) believed that consumers were unaware or unconcerned about the use of antibiotics in pigs. In their opinion, consumers were oblivious and disconnected from the rural reality and were concerned mostly with the price and quality of the goods. Yet, a third (36%) of the farmers mentioned that they believed that consumers cared about how antibiotics were used on their farms and linked these beliefs with concerns of maintaining a positive image of pork among consumers and with the potential traceability of problems that could be associated with their farms (F54a; F20a).

Moreover, some farmers told us that they did not eat pork from animals that received antibiotics, and some of them stated that they fattened animals without antibiotics for their own consumption (F25a; F23a; F61c).

3.4.8 Reducing AMU—a Distant Idea for Farmers

Farmers expressed divided opinions about the prudent use of antibiotics in Brazilian pig farms. For 48% of farmers, the use of antibiotics in pig farming in Brazil was adequate, and 43% believed that the use was not rational (9% did not know how to express an opinion on this subject). Sixty-six percent of farmers had some knowledge about prudent anti-biotic use policies and 63% showed negative attitudes towards a hypothetical scenario of restriction of the use of veterinary antibiotics; even those favourable to these measures did not consider it a viable scenario. Farmers cited economic, productive, health and cultural barriers to adopting changes in the use of antibiotics. In their opinion, limiting the use of antibiotics for prophylactic purposes would increase production costs and undermine small farmers' survival (F38a). They believed that removing antibiotics would aggravate the economic crisis and demand capital for structural investments (F4a); some mentioned problems with biosecurity (F2c; F1b; F58b).

In the assessment of some farmers, cultural elements such as Brazilians' disregard for rules and the farmers' dependence on the use of antibiotics made measures of the prudent use

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of antibiotics unfeasible (F9a; F32a). The difficulties of the competent bodies to inspect compliance in the national territory were also raised as an obstacle that would prevent full control of the use of antibiotics (F42b).

One view identified in the group was that the prudent use of antibiotics in animal production in Brazil depends on changes in current production models (F16a). Other suggestions for changes to reduce dependence on antibiotics were the use of pigs genetically more resistant to diseases, natural additives or improvements in animal welfare (F33a; F22a).

3.5 DISCUSSION

The information provided by the farmers in this study suggests that their pigs were exposed to large amounts of antibiotics for long periods. When asked about the general use of antibiotics on pig farms, almost half of the farmers considered that the use was indiscriminate; however, they attributed this reckless conduct to other farmers and not to themselves. Antibiotics were part of a repertoire of routine practices, which these farmers considered legitimate and beneficial. In addition to relying on the effectiveness of antibiotics, pig farmers found it difficult to change deep-rooted habits. Changing routine behaviours is a challenge, especially when what is expected is a drastic change with results that are difficult to perceive (PANNELL et al., 2006; SPEKSNIJDER; WAGENAAR, 2018), as is the case with AMR. The relatively low adoption of biosecurity and hygiene measures, the constant use of the term “antibiotic shocks” to refer to the strategic use of antibiotics in pig diets for preventive purposes and reference to antibiotic therapy as a simple and routine practice suggest a social conformity with the use of antibiotics as a preventive strategy. This, in turn, explains the low support expressed for policies aiming at reducing AMU. Pig farmers saw more advantages than risks in the AMU, and considered the cost of antibiotics high, however justified due to their efficiency; this illustrates the dependence on antibiotics of modern livestock production systems, in which the advantages of use are more noticeable than their harmful consequences.

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Our findings that pigs received preventive doses of antibiotics for a large proportion of their lives suggest that focusing public policies of prudent AMU on reducing or banning antibiotics use for growth promotion may be insufficient and disconnected from the actual use of antibiotics on Brazilian pig farms. Instead, it is important to regulate the use of preventive and curative antibiotics on pig farms. In Brazil, there are no restrictions on the therapeutic and prophylactic use of antibiotics; Brazilian regulations on antimicrobials refer to technical standards for the manufacture of medicated feed and other regulatory instructions that limit or prohibit the use of certain active ingredients as growth-promoting additives (BRASIL, 2021). Importantly, some of the antibiotics cited by the farmers in this study are classified by the WHO and OIE as "Highest Priority Critically Important Antimicrobials" (OIE, 2018; WHO, 2019). Policies aiming at the prudent use of antibiotics do not recommend the use of several principles mentioned by farmers, such as aminopenicillins, tetracyclins, macrolides, quinolones and amphenicols for the prevention or treatment of pigs, given their association with AMR in humans. Other studies identified the use of the same active principles in pig farms in Brazil and in other countries (DUTRA et al., 2020; DYAR et al., 2020; STRÖM et al., 2018). The choice of broad-spectrum active ingredients may suggest the presence of AMR in these herds. KIRCHHELLE (2018) warned of the risks of running out of broad-spectrum antibiotic options, as the ability of bacteria to become resistant is more efficient than the speed of pharmaceutical companies in developing new drugs.

Low adoption of biosecurity and hygiene measures was allied to the excessive use of antibiotics. Additionally, inappropriate practices identified include continuous use of preventive antibiotic therapy, "antibiotic shocks" (i.e., strategic periodic metaphylactic treatment), inappropriate dosages and dilutions and insufficient treatment time when using injectable antibiotic treatments. Excessive AMU in livestock production is discussed as a low-cost substitute for good practices including good hygiene measures to prevent infections in livestock (VAN BOECKEL et al., 2017) as confirmed in this study and in others carried out in

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Brazil (DUTRA et al. 2020). Incentives to reduce AMU result in the adoption of more costly or laborious alternatives to control infection, such as vaccinations, reducing stocking density and cleaning (BELAY; JENSEN, 2020; STYGAR et al., 2020). Those studies further confirm that antibiotics are often used as substitutes for these practices and that it is possible to reduce AMU when these practices are adopted. Farmers were aware of the need to improve the biosecurity conditions on their farms; however, like French pig farmers (DAVID et al., 2020) they showed negative attitudes towards adopting biosecurity measures, because they considered them burdensome and laborious. Many management practices used in the visited farms, like early weaning, repeatedly mixing unknown animals and cage housing for sows, negatively impact pig welfare and are associated with high levels of stress (PEDERSEN, 2018). However, as shown in our accompanying study (ALBERNAZ-GONÇALVES et al., 2021), farmers were not motivated to introduce practices aimed at improving welfare. The prophylactic use of antibiotics is still widely present in the pig production chain in several countries (ADEKANYE et al., 2020; STRÖM et al., 2018), even with several studies showing that good husbandry practices and biosecurity allow reduced use of antibiotics (COLLINEAU et al., 2017; POSTMA et al., 2017). For example, in a comparative study among herds in European countries (Belgium, France, Germany and Sweden), late weaning and investing in efficient external biosecurity measures helped farmers reduce the use of antibiotics (POSTMA et al., 2016). Other research showed that it is possible to avoid prophylactic use of antibiotics with low productive and economic impacts, provided that the management and welfare of pigs is improved (DIANA et al., 2019; ROJO-GIMENO et al., 2016).

Farmers felt confident and able to diagnose diseases and medicate animals without the need for a veterinarian and took on that responsibility, as identified in other studies (DYAR et al., 2018, 2020; LITTLE et al., 2021; STRÖM et al., 2018). Additionally, confidence in technical assistance was compromised by commercial conflicts of interest, since the sale of products was associated with veterinary assistance in most cases. This was reinforced by the

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practice of agro-industries and cooperatives to pass on lists of symptoms and medicines for farmers to apply on the farm. Thus, in this com-munity, veterinarians lost the status of guardians of animal health and became sellers, similar to other studies carried out on the Belgian–Dutch border and in Thailand, Cambodia and China (CAEKEBEKE et al., 2020; DYAR et al., 2020; LEKAGUL et al., 2020; STRÖM et al., 2018). Compliance with the techniques recommended by the veterinarian is associated with the level of confidence that the farmer has in relation to the behavior and competence of the veterinarian (RITTER et al., 2019). Mistrust in the quality of technical assistance weakens bonds of trust between farmers and veterinarians, with negative con-sequences for the implementation of policies for the prudent use of antibiotics.

Negative attitudes and scepticism regarding the policies to restrict AMU and prudent AMU in Brazil were not surprising, given the scenario described about farmers' knowledge about AMU and AMR, added to the perception expressed by many that they made a rational use of antibiotics. Additionally, the farmers presented many arguments to justify their position against the policies of prudent use of antibiotics, including financial insecurity of the sector, the increase in production costs and the health problems present in the herds. Farmers in other countries have also identified the same economic and health barriers as important limitations to restricting antibiotics in pig farming (COYNE et al., 2019; GOLDING et al.; 2019). As in the study by Golding et al. (2019) farmers showed mistrust in the capacity of government agencies to inspect and enforce rules, which contributed to their negative attitudes towards policies of prudent use of antibiotics. Failure to enforce rules was revealed in the farmers' access to antibiotics from vendors without prescription, as reported previously (BRAN et al., 2018; OLMOS et al., 2018). Indeed, systems of control of the prescription and sale of antibiotics are considered essential to the implementation of policies for the prudent use of antibiotics (AGERSØ et al., 2011; DUPONT et al., 2017). In contrast, free access to antibiotics without sales control encouraged the imprudent AMU by the farmers in the present study.

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The lack of knowledge about various aspects of AMU and AMR may explain why, although farmers identified some triggering factors for AMR, many failed to establish a connection between AMR and the continued use of antibiotics they described in the inter-views. Most farmers did not see a relationship between human and veterinary antibiotics or the AMU in livestock as a risk factor for AMR in humans. Other studies have also shown that farmers either ignored (STRÖM et al., 2018) or showed scepticism about the role of intensive livestock farming as a contributing factor to the spread of AMR (EKAKORO et al., 2019; GOLDING; et al.; 2019). Some farmers acknowledged the risk of antibiotic residues, but exclusively residues in meat associated with not meeting the antibiotic grace period, similar to other studies (OM; MCLAWS, 2016). The farmers' lack of knowledge about the risks of AMR put their health at risk, given the importance of occupational transmission of AMR (SMITH et al., 2013; VAN GOMPEL et al., 2020). In addition, the lack of awareness about AMR can hinder the implementation of practices aligned with the prudent use of antibiotics (GOLDING et al., 2019; VISSCHERS et al., 2015). Farmers in this study seemed unwilling to make changes that are needed to allow reducing of AMU. Underlying this resistance to change was the feeling that reducing AMU under the current circumstances would be impossible. In our opinion, farmers were correct in their arguments that it is impossible to sustain the current production system without high amounts of AMU. Furthermore, we identified economic, technical and social factors that limit farmers' autonomy and power to change practices. As discussed by others (CHANDLER, 2019; KIRCHHELLE, 2018a; KIRCHHELLE et al., 2020) antibiotic restriction policies based on individual attitudes may not be enough to solve the AMR problem. Instead, collective measures are needed by groups with greater autonomy than pig farmers (CHANDLER, 2019), such as agro-industries, pharmaceuticals and animal health inspection bodies. Yet, the involvement of all stakeholders, including farmers, is essential to guarantee a sustainable transition to prudent AMU; as warned by VON KEYSERLINGK and HÖTZEL, (2015) if changes in production systems are forced by external pressure, rather than by

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initiatives from the sector, decisions may not be fully linked to farmers' concerns and priorities, which can generate economic risks for producers not prepared to respond.

Some farmers believed that changes in the rules for the use of antibiotics would come due to international demands, whereas national consumers and the risk of AMR, on the other hand, appeared as weak motivators for changes in behaviours regarding AMU. Farmers downplayed the role of Brazilian consumers as a driver of change, considering them not informed or interested in relation to the practices adopted on the farm. However, several studies have shown that lay citizens and consumers are increasingly concerned about issues related to livestock production, including the use of antibiotics (CLARK et al., 2019; TEIXEIRA et al., 2021; YUNES et al., 2017) and some are aware of the relationship between AMR and the use of antibiotics in livestock production (BUSCH et al., 2020; HÖTZEL et al., 2020).

This study was restricted to the social context of one of the main pig-producing regions in Brazil. It is important to note that more quantitative and qualitative studies are needed to describe the situation regarding the use of antibiotics in a national context. In the meantime, the results of this study, even if localized, can provide us with a perspective of Brazilian farmers' view on the problem of AMR and knowledge gaps that can be explored by other research focused on the prudent use of antibiotics.

3.6 CONCLUSIONS

Farmers are the direct guardians of pigs' health and welfare; thus, they are essential for maintaining and complying with prudent AMU in the industry. Our qualitative study provides evidence of farmers' unwillingness to adopt AMU practice changes, rooted in an unchallenged dependency on antibiotics. These farmers relied on antibiotics for disease prevention, whilst neglecting biosecurity and good animal welfare practices to reduce infection pressure and keep their pigs healthy. Equally, farmers reported mistrust, unpreparedness and misregulation from veterinary health services and the production chain. Altogether, this supports the AMU status

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quo, removing any pressure to change. Moreover, national public health concerns or consumers' views did not compel them to change either. For this reason, we emphasize the importance of education and training of pig farmers and other rural workers regarding prudent AMU in pig farming and the risks of AMR. However, although transitioning to a more prudent AMU requires individual behavioural changes, we reinforce the idea that pig farmers are not sufficiently autonomous to determine substantial changes to reduce antibiotic use. Just as farmers indicated, we see external markets as positive catalysts for change. Yet, for this to work, national considerations and support structures have to be in place. If not, we forecast a forced loss of farmers' diversity and increased stress in rural areas' livelihood structures, which may increase the existent mistrust between farmers and regulatory institutions and national consumers.

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4.MY PIGS ARE OK, WHY CHANGE? – ANIMAL WELFARE ACCOUNTS OF PIG FARMERS

R. Albernaz-Gonçalves, G. Olmos, M.J. Hötzel

4.1 ABSTRACT

Intensive pig production systems are a source of stress, which is linked to reduced animal welfare and increased antimicrobial use. As the gatekeepers of the welfare of the animals under their care, farmers are seen as the stake- holder responsible for improving animal welfare. The aim of this study was to explore the knowledge and attitudes of pig farmers towards pig welfare and the impact of such attitudes on farmers' selection of management strategies on the farm. We conducted in-depth semi-structured interviews with 44 pig farmers in one of the main pig producing regions of Brazil. Interviews covered knowledge and attitudes towards pig sentience and behaviour and welfare-related issues commonly observed in intensive pig farms (belly-nosing, fights, tail-biting, diarrhoea and castration without pain control) and farmers' conception and attitudes towards pig welfare. We identified many management and animal-based indicators of poor welfare, such as the use of painful and stressful management practices and use of environments that limit the expression of natural behaviours. However, most farmers were satisfied with animal welfare standards at their farms. Farmers' perceptions are aligned with their understanding of animal welfare. Although they identified all the dimensions that impact the welfare of a pig on a farm (affect, biological functioning and naturalness), their social reality, industry demands and available advice pushed them to perceive their range of action limited to biological and environmental aspects of the animals that do not necessarily benefit affective state. This precluded farmers from making associations between good health and the animal's ability to express a full behavioural repertoire, as well as from viewing abnormal behaviours as problems. The negative consequences for the welfare of the animals were commonly alleviated by routines that relied on constant use of medication, including high dependence on antibiotics. Expressions of estrangement from the production chain were common voices among the participants. This suggests that farmers may not be sufficiently informed or engaged in responding to consumers' expectations and commitments made by companies, which can pose a severe economic risk for farmers. The findings of this study indicate that economic, technical and social factors restrict farmers' autonomy and their ability to perform their role as stewards of animal welfare. (Re)connecting different human, animal and environmental interests may be a step to changing this scenario.

4.2 IMPLICATIONS

Detailed accounts of intensive pig farmers revealed a dissonance between attitudes towards pigs' sentience, conceptions of farm animal welfare and on-farm management practices. Social context, industry demands, and available advice seemed to push farmers to

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perceive their range of action as limited to improving biological and environmental determinants of basic welfare, whilst improving mental state was be - yond their ability. Moreover, we found evidence of disconnection with industry and consumers' demands/expectations regarding farm animal welfare. Our findings suggest that farmers have an undermined self-determination and autonomy to be critical of their practice and change it, preventing them from successfully caring for the welfare of their animals.

4.3 INTRODUCTION

Intensive pig production systems are a source of stress and reduced animal welfare. In these systems pigs are often housed in small or barren environments that prevent them from exhibiting their natural behaviours. This, in turn, increases the frequency of abnormal and stereotypic behaviours, indicating stress (CRONIN, 1985). Other common stressors of intensive farming are chronic hunger, painful mutilations, early weaning, high stocking density and successive social regrouping (PEDERSEN, 2018; READ et al., 2020). Ultimately, the pigs' immune system is compromised, making it susceptible to infections (FILIPE et al., 2020). In an attempt to ensure herd productivity and prevent outbreaks of infection, intensive pig farms rely upon antimicrobials and thus maintain the herd health until slaughter (SJÖLUND et al., 2016). Such use of antimicrobials in food-producing animals is a significant contributor to the to the global issue of antimicrobial resistance and this problem has led to increased regulation of antimicrobial use in the veterinary sector (VAN BOECKEL et al., 2015, 2019). Policies that aim to control the spread of antimicrobial resistance call for monitoring/reducing antibiotic use and fostering good husbandry practices, including improving animal welfare (Magnusson et al., 2019). This adds to growing public pressure for food-producing animal sectors to act more coherently with sustainability and animal welfare goals (PEDERSEN, 2018).

However, despite growing scientific understanding of animal welfare problems and solutions, which supports some local and international regulatory measures, many contentious practices are still the norm in farms throughout the world (PEDERSEN, 2018; VON KEYSERLINGK; HÖTZEL, 2015). Farmers are primarily affected, both economically and socially, by the challenges the animal industries are facing. As the gatekeepers of the welfare

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of the animals under their care (MEIJBOOM, 2018) they are seen as the stakeholder responsible for implementing changes to benefit welfare. However, developing new practices that improve animal welfare is not enough to change the status quo, as innovations often fail to address the farmers' perceived constraints (WEARY et al., 2016) especially those of an economic nature (MOLNÁR; FRASER, 2020; SCHUKAT et al., 2019; SPOONER et al., 2014). Listening to these key stakeholders is thus essential to help formulate and enact sustainable policies aimed at improving animal health and animal welfare. This information is especially lacking for some top producing countries like China, USA and Brazil, as the vast majority of contributions to the literature on this issue are from European countries (e.g., BERGSTRA et al., 2015; KAUPPINEN et al. 2012; MOLNÁR; FRASER, 2020; TUYTTENS et al., 2012). This study aimed to explore the knowledge and attitudes of intensive pig farmers towards pig welfare in one of the main pig-producing regions in Brazil and the impact of such attitudes on farmers' selection of management strategies on the farm and their intentions to change.

4.4 MATERIALS AND METHODS

This work is part of the research project "Knowledge and attitudes of Santa Catarina's pig industry on antibiotics, bacterial resistance and animal welfare" conducted by the Applied Ethology Laboratory of the Federal University of Santa Catarina - LETA-UFSC. This particular study followed a qualitative approach to obtain a detailed account of animal welfare views of pig farmers, acquired through in-depth semi-structured interviews.

4.4.1 Study location

Brazil is the world's fourth largest pig producer, following China, the European Union, and the United States of America (FAO 2020). Santa Catarina (SC) state holds the largest production in Brazil (25% of the sows), and is a main livestock export hub, given its special sanitary status and quality of production (SEBRAE and ABCS 2016). Tubarão is the second-largest pork producer region in Santa Catarina, with 19 municipalities and around 1,500 registered pig production units housing a total of 100,000 sows (CIDASC, 2018, personal communication). Braço do Norte (located between 28º 16' 30" S and 49º 09' 56" W), a

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municipality of the micro-region Tubarão, was chosen as the study location because it presents a diversity of conditions found in pig intensive production systems, including labour type, herd size, production types and production models. Pig farming in Braço do Norte focuses on the production of weaned piglets for fattening, but also has full-cycle farms that sell finished pigs for slaughter in small-scale local slaughterhouses. Pig production in the southern region of Brazil is also characterised by specialised production segregated in multiple sites and a smaller number of full-cycle sites. In the study region, the majority of the farms (69.5%) are considered medium-sized (between 300 and 1000 housed pigs) and the predominant production models include integrated pig producers (45%), cooperatives (39%) and independent producers (16%) (SEBRAE and ABCS 2016).

4.4.2 Participant recruitment

The recruitment of participants was done through a network of contacts from the first author. The first 12 participants were recruited directly and the other farmers were identified via a non-probabilistic snowball sampling method. This method is suitable for accessing information from groups that are difficult to reach (ROLLER; LAVRAKAS, 2015) in this case pig farmers of SC state. Difficulties to contact farmers included internet access, distance from urban areas, and an outdated association list. Initial contact with potential participating farmers was done mainly over the phone, but in some instances, a farm visit was necessary to extend the invitation. Once the farmer agreed to participate, a visit to the farm for the interview process was scheduled.

In total we interviewed 63 pig farmers, of which 44 interviews were considered complete regarding the aims of the present study, of exploring knowledge and attitudes of intensive pig farmers towards pig welfare. All pig farmers (n=63) were willing to participate; however 19 interviews could not be used after the company withdrew authorisation (n=5), the interview was interrupted by the participants that asked to stop because they were either tired or needed to do some routine activities (n=10); or poor audio quality did not allow transcription (n=4).

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All interviews were done face to face, in Brazilian Portuguese, between January and February 2019. Before beginning the interview, the participant was given and read the Free Informed Consent Form, which contained all the information relevant to the interview. Only after the consent form was understood and signed, the audio recording and interview process started. The participant could ask questions, interrupt the interview or even withdraw from the study at any time. The interviews were carried out by the same interviewer in order to ensure consistency of the questions. The average duration was of 37m per interview (between 15m and 1h12m).

The interviews were conducted in two stages. First, we interviewed 40 pig farmers, analysed the responses obtained, and returned to the study region to conduct another 23 interviews. After the second analysis no new elements were identified, thus it was considered that the number of interviews provided good data saturation, i.e., they provided an in-depth, diverse and rich account of the topic, and no new information was obtained with the further addition of participants. Sample size for this type of research depends on the diversity within the population of study and the amount and richness of data collected from each participant (BRAUN et al., 2019; BRAUN; CLARKE, 2006a). Participants represented a variety of production contexts and demographics (Table 8 and Table 9), and provided a rich data sample.

4.4.3 Interview script

The interview script contained semi-structured and open-ended questions (Appendix C). The interview was divided into four sections: 1) sociodemographic and farm information, 2) discussion of at least two out of five specific health and welfare topics (see description below); 3) attitudes about pigs and pigs' cognitive and emotional capacity; and 4) opinion on a hypothetical scenario of animal welfare certification.

The five topics available for discussion were, 1) diarrhea in weaned piglets, 2) belly-nosing, 3) fights, 4) tail biting, and 5) piglet castration. Each participant was invited to discuss in more detail at least two topics. One of the two topics discussed was selected based on the type of production of each participant, and the second was randomly chosen to achieve an approximately similar number of responses for each theme. The discussion of topics was around

participants' personal experience on their farm and farming community. We asked about the frequency of occurrence of problems on farm and in the area, and which of the topics mentioned they considered more important. Within the two topics specifically discussed with each farmer, we asked them to mention what were the likely causes, whether they had considered any mitigation or preventive measures, and if they were feasible options to be used on their farm. The interviewer prompted a list of potential options for each topic in the event the farmer did not provide any personal account during the discussion.

Participants were asked for their opinion regarding the ability of piglets to feel pain during castration and alternatives (immunocastration, castration with pain control and fattening entire males).

All participants answered questions regarding their opinion regarding pigs' ability to express emotions and some attitudes towards pigs. Participants who had breeding farms (full cycle or piglet producing unit, n = 33) were asked about abnormal behaviours of sows (dog sitting position and bar biting) and about their attitudes regarding the adoption of group housing for gestating sows. Farmers' responses were recorded using a scale or option grid (Supplementary Table S2), and comments were also followed up in conversation. At the end of the interview, the participant was presented with a hypothetical scenario of certification of farms for a fictitious animal welfare label. This is how it was described to farmers: Let's assume that your farm will be part of an animal welfare certification program in which you will receive additional benefits for producing pigs within certain animal welfare standards. According to your conception of animal welfare, what would your farm need to change to be certified? Lastly, the interviewer asked what was, in the participant's perception, "a pig with a high standard of animal welfare" and what he/she considered necessary to be able to say, "in my farm I care about animal welfare".

4.4.4 Data analysis

We used an inductive (reflexive) thematic analysis approach (see BRAUN et al., 2019; BRAUN; CLARKE, 2006). This type of analysis is not allied to any specific theoretical framework, thus providing a flexible approach that can be used to examine a variety of issues,

going through and beyond researcher insights or expectations. After exhaustive reading of the transcripts for familiarization with the data, codes were generated and developed into themes. The approach was inductive, where the analytic process starts from the data, working "bottom-up", and thus grounded in the interviewees' responses, minimizing biases. Through interactive discussion among the authors, each theme was refined, generating names (titles) and definitions for each theme. Selected extracts that represent the themes were translated by MJH for presentation. Analysis was done with the aid of the NVivo Qualitative Data Management Program (version 11, 2015; QSR International Pty Ltd., Doncaster, VIC, Australia).

4.5 RESULTS

Demographic and farm data are shown in Tables 8 and 9. The participating farms had between 50 and 1200 sows or finishing pigs, including full cycle (or farrow-to-finish) farms, piglet producing units (or breeding farms), growers and fattening units. Farmers were either independent, members of one of two integrated companies, or members of one of three different cooperatives. The interviewees considered themselves as experienced pig producers, with 82% of the participants having at least 10 years of experience in the industry.

Table 8**.** Demographic characterisation of the visited farms (n = 44) split by productive sector link

Farm type	Independent	Cooperative	Integrated	Total n (%)
Farrow-to-finish	15	0	0	15 (34)
Breeding farms	6	4	8	18 (41)
Growing farms	1	0	1	2 (5)
Fattening farms	6	0	3	9 (20)
Total	28 (63)	4 (9)	12 (27)	44 (100)
Herd size (number/herd)				
≤100 sows or finished pigs	5	0	0	5 (11)
101-500 sows or finished pigs	16	1	4	21 (49)
501-1000 sows or finished pigs	4	1	4	9 (20)
>1000 sows or finished pigs	3	2	4	9 (20)
Other farm activities				
Pig farming only	2	0	3	5 (12)

Dairy cattle	24	3	8	35 (80)
Aquaculture	6	0	1	7 (16)
Beef cattle	1	1	1	3 (7)
Labour type				
Family and hired	11	4	6	21 (47)
Family	15	0	5	20 (46)
Hired	2	0	1	3 (7)
Type of gestation housing (n=33)				
Mixed[1]	11	4	5	20 (61)
Individual	10	0	3	13 (39)
Group	0	0	0	0

[1]Mixed: farms that had individual and group housing

Source: Author

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Table 9. Demographic data of the interviews (n = 44)

Demographics	n	%
Sex		
Male	33	75
Female	11	25
Work experience		
Up to 5 years	3	7
Between 6 and 10 years	5	11
Between 11 e 15 years	6	14
Between 16 e 20 years	10	23
Over 20 years	20	45
Education		
Elementary school	11(8M, 3F)	25
High school	26 (21M, 5F)	59
Higher education	7(4M, 3F)	16

Source: Author

4.5.1 Farm description/background

Commercial dairy cattle farming was often present in association with pig production (80%); a primary motivation cited by participant farmers for having finishing units was the production of pig manure for fertilising pastures for cattle. All farms had crops, mainly corn, to feed the animals. None of the visited farms used bedding, and all pigs were housed in structures with concrete flooring. Some units linked to integrators were building group gestation housing; however, these farms still maintained individual gestation crates for oestrus detection and artificial insemination. Participants from cooperatives and integrators mentioned that some companies had signed commitments to change the gestation systems, with deadlines for the farmers to adapt until 2026 (SUINOCULTURA INDUSTRIAL, 2017).

Farmers received technical assistance from veterinarians and agricultural technicians from companies that sold animal nutrition products (45%), from cooperatives and integrators

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that provided veterinarians or agriculture technicians (36%), or called a veterinarian only for emergencies (19%). Farmers who received regular assistance reported that the frequency was weekly (55%), every two weeks (16%) or monthly (29%).

4.5.2 Farmers' perceptions of sentience and empathy towards the pigs

Farmers perceived pigs as sentient beings, capable of feeling basic emotions, both negative and positive. All participants agreed that pigs are capable of feeling pain (*"The pig is like that, it's not that he doesn't feel pain, it's that he doesn't mind. He is more stubborn than crazy"* – Farmer 59) and most agreed that they could feel fear (91%), stress (95%), joy (86%) and boredom (57%). Farmers agreed that pigs are stubborn (98%), gluttonous (93%; *"They'll eat until they burst if you let them"* – Farmer 50), intelligent (73%; "*Yes, they learn things that make you wonder… They know how to find the water, you can change the place, like the feeder, they will find it. They are very smart"* - Farmer 34), dirty (64%) and friendly (52%).

However, although the farmers recognised pigs as sentient beings, they had negative attitudes towards practices that could improve pigs' welfare or minimise pain. Also, not all farmers recognised the pain caused by their routine practices. For example, only 47% considered castration an extremely painful practice *("Ah it must hurt, it's done without anaesthesia, of course, it hurts"* – Farmer 16; "(...) *they rub their butts after they are castrated"*- Farmer 55), but 22% said it causes little to no pain (*"No, it's okay to do castration without medication. From one day to the next you look, and it's already dry, he's brand new"* – Farmer 16). Moreover, most farmers rejected alternatives to surgical castration aimed to minimize pain (Table 3). Perceived difficulties of management and increased production costs (69%) was the main reason for rejection of castration with pain control. Some farmers who used immunocastration (27%) were satisfied that they no longer had to do it surgically (*"No more castration. Because they lose a lot of weight, right? It's enough they cut off their tails…"* – Farmer 03).

We observed similar attitudes towards the adoption of practices that could help reduce the frequency of abnormal and stereotyped behaviours, such as offering substrate, rearing in family systems, pre-weaning socialisation and group housing for gestation (Table 10).

Participants rejected all alternatives that involved additional production costs or that were laborious (*"It is not possible to raise family lots, because you can't have all the siblings in the same pen.… a sow has 10 to 15 piglets, we won't have a pen for only 10 to 15 piglets from that sow"* - Farmer 34; *"Group housing for gestation is more laborious, costs more and is more difficult to manage. It does not improve productivity and it costs more"* – Farmer 14; *"Offering substrate? It's an idea but I don't know if it would be viable. The cost, and being able to manage it"* – Farmer 15).

All farmers recognised that management practices may lead to pigs' stress (*"If stocking density is too high in a pen they get stressed - lack of food, lack of water. It happens a lot"* – Farmer 34). Also, most (80%) believed that stress may lead to the occurrence of illness (*"They can get sick, yes, they get ulcers, a big animal, if it is stressed, it gets ulcers"* – Farmer 50), and especially to thermal stress (*"The temperature fluctuates and their organism suffers, lowers immunity, they are more vulnerable to contracting viruses"* – Farmer 3). Likewise, they believed that good management could reduce the incidence of stress. Yet, the changes farmers proposed were mostly related to basic management aspects of biosecurity and hygiene of the facilities (*"Yes, it is possible with good cleaning, good water, good food"* – Farmer 34; *"Leaving the pens clean, disinfecting, these are ways to use fewer antibiotics"* – Farmer 20).

Table 10. Farmers' attitudes towards pain and alternative castration and management methods.

Do you judge the following alternative methods of castration to be viable [*1]	Impracticable n (%)	Viable n (%)	Do not know n (%)
Castration with pain control	20 (77)	0	6 (23)
Imunocastration	5 (19)	9 (35)	12 (46)
Entire pigs	23 (88)	2 (8)	1 (4)
Do you judge the following alternative to be viable[*2]			
Offering substrate	41(93)	2 (5)	1 (2)
Familiar group rearing	40 (90)	4 (9)	0
Pre-weaning socialisation	44 (100)	0	0

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Group housing gestation	21 (48)	10 (22)	13 (30)

*[1]Questions about castration alternatives and abnormal behaviours were randomised (n =26).
[2] All participants answered this question (n =44)

Source: Author

4.5.3 Farmers' conception of pig welfare

We used a word cloud (Figure 3) to capture the participants' conception of pig welfare. Farmers' mostly explained animal welfare in terms of biological aspects such as health and availability of drinking water and food (*"Pigs with welfare are well cared for, are in a suitable place, with food, with water, they receive the medicines they need"* – Farmer 10) and often referred to environmental aspects such as climate control and cleanliness ("*They need to be in a good environment that is not hot, and that is clean too. That's what welfare is"* – Farmer 23).

Figure 3. Word cloud with participants' most frequent expressions about the concept of animal welfare in pigs

Source: Author

Some participants described animal welfare in terms of "a calm or not stressed pig" (*"A pig with good welfare means that he is not stressed, he is lying there, eating well"*- Farmer 3). Although mistreatment was identified as detrimental to the welfare of pigs, some hinted that

it is not always possible to avoid it (*"…no mistreatment, not hitting for no reason. But the production practices, those you cannot change. It is stressful, but in the same way as we, human beings, also have stress throughout life, the pigs also have it* (a stressful life). *Welfare is not to hurt them, and being as gentle as possible"* – Farmer 2).

Group housing in gestation sows was used by many farmers as a synonym of animal welfare: *"Animal welfare is because of the sows, isn't it?"* (Farmer 26). Some farmers associated the welfare of pigs with free-range systems and freedom to express the species' specific behaviours, but not as a real possibility (*"I don't know, to be comfortable, they should be free on pasture so they would be very happy"*, Farmer 11; *"Animal welfare, if you think about it, they should be free* (referring to pigs*). But we try to provide for them, while they are on the farm, we avoid mistreatment, we give them the best, the best condition for them to eat, to not run out of water, to not get sick…"* (Farmer 15).

When asked about a hypothetical animal welfare certification scenario, 47% said they already did enough regarding animal welfare (e.g., *"I think our farm provides welfare, nowadays it is possible to adapt everything to the company's animal welfare* (requirements)" – Farmer 43; "*There is no way to change a lot because of animal welfare. Most (sows) are already in group housing; we can't do much more differently"* – Farmer 11). Aspects related to the pigs' affective states were not mentioned as areas of welfare improvement on farms. Of the farmers who associated animal welfare improvements with better infrastructure, 21% talked about adding air conditioning, and 25% about building new or bigger facilities to reduce stocking density in the growing and finishing phases (e.g., *"I think improving the nursery and finishing facilities. Improve our sows' barn; we could improve the flow of manure, make it drier"* – Farmer 15; "*... pigs with more space, because the looser they are the more welfare they have ... Building it from scratch"* – Farmer 23). The other 9% mentioned transitioning to group housing in gestation and 7%, adopting better hygiene and biosecurity practices.

4.5.4 Farmers' perception of management practices that influence animal welfare

Out of a total of 44 farms, 33 were breeding farms (breeding farms and farrowing to finish). Farmers' description of the management at nurseries revealed challenges for animal

welfare. In general, farmers did not supervise births (except 22%) and only 49% registered neonatal mortality and its causes. Although they did not keep mortality records, 91% of the farmers identified crushing by the sow as the leading cause of mortality in newborn piglets. They also reported extensive use of stressful and painful practices, especially so in the first week of life, without applying any form of pain relief. All farms did tail docking within the first three days of life, 73% used tooth clipping and 60% of males were surgically castrated (*"At birth, we wear the teeth. Because if we don't, they hurt the sow's udder, they don't even suck"* - Farmer 18). Although during painful practices piglets received preventive medications for neonatal diarrhoea and arthritis, nothing was done to minimise the pain, because it was believed that such pain is momentary ("…*castration, tail cutting… It does hurt, sure. It's done without anaesthesia, without anything. But I think it's just a little, just when it's done* (referring to the pain") – Farmer 43).

Diarrhoea was the main concern for 89% *("For us it's diarrhoea, because the others don't happen here"* – Farmer 16; *"Diarrhoea is more serious, because the piglet won't grow"* – Farmer 14). The factors they related to diarrhoea were temperature variation, poor hygiene, nutritional deficiencies and high stocking density (Table 11). When asked about potential causes of the dissemination of diarrhoea in weaned piglets, no farmer mentioned early weaning or mixing piglets from different origins (different farms, buildings, or litters) as risk factors.

Table 11. Causes of post-weaning diarrhoea according to participants

Causes related to post-weaning diarrhoea (n=20)				
Causes*	Very related n (%)	Related n (%)	Somewhat related n (%)	Unrelated n (%)
Temperature variation	19 (95)	0	0	1 (5)
Nutrient-poor foods	15 (75)	3 (15)	0	2 (10)
Mixing of pigs of different origins	2 (10)	4 (20)	3 (15)	11 (55)
High stocking density	9 (45)	4 (20)	3 (15)	4 (20)
Early weaning	2 (10)	7 (35)	5 (25)	6 (30)
Poor hygiene	18 (90)	0	0	2 (10)

* Participants were presented a list of events potentially related to post-weaning diarrhoea and asked to assign a causal relationship according to their understanding (i.e., more or less related to the event).

Source: Author

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Cross-fostering was performed in 80% of the breeding and farrowing to finish farms (n=33) and in 86% of these it was done up to 24 hours after birth. Farmers reported that this management practice could occur several times in the same lactation and among piglets of different ages. Some participants performed this practice whenever they noticed low weight piglets. Groups were made to match weight, although there was no standard management practice between the farms.

Some farmers left smaller piglets longer with nursing sows reserved for that purpose. Farmers gave conflicting reports regarding their satisfaction with this practice (*"I use surrogate sows. I reserve an older sow or two, almost ready to be weaned. It is time consuming, but if you do everything right it works"* – Farmer 19; "*We only use a nursing sow when we wean them, but the runts remain with the sow. We do it* (cross-fostering*) every Thursday… if we see some that are getting very behind, then we leave them longer with the sow. … but we see that it hardly pays off"* – Farmer 17). Cross-fostering also stressed the sows. According to some participants, the sows did not easily accept new piglets.

Farmers identified some management practices as unsatisfactory or stressful for animals, but necessary and inherent in pig production. For example, weaning was done between 24 to 28 days of age in 80% of the 33 farms that had piglets. Some farmers perceived the benefit for the piglets of later weaning (*"It depends on the weight, in general, it is at 24 to 28 days, sometimes later. But sometimes we wean piglets at 15 days with 7 or 8 kg - though it is not cool, because they go to the nursery and will suffer more because they are so young"* – Farmer 03).

The solutions for some of these laborious and stressful practices (for them and pigs) often involved the use of preventive medications, mostly antibiotics. Weaning was one of the stressors associated with the use of medications; all farms with weaned piglets (farrowing-to-finish, growing farms, fattening farms; n=25) used preventive antibiotics in the feed. To relocate piglets to new fattening units, the pigs received antibiotics and anti-inflammatories in the feed and water. Farmers described that, at weaning, piglets were segregated by sex, mixed and loaded into a truck with piglets from different farms, to be transported to nurseries in the region or to farms belonging to integrators located in western Santa Catarina. In this case, the piglets could be transported over long distances, for up to 12 hours of travel. Interviewed farmers in

growing and finishing farms (n=15) reported frequent use of antibiotics and NSAIDs to prevent fevers when receiving piglets (*"We use metamizole* (antipyretic and painkiller) *in the water when they arrive because they arrive with a fever, they are stressed because of separation from their mother, because of the truck, so we need to put something in the water"* – Farmer 39; *"In the pre-starter feed, amoxicillin (antibiotic) in the nursery, first tiamulin* (antibiotic), *then another shock at the beginning of the growth phase with tiamulin* (antibiotic) *and, at the beginning of the finishing phase, florfenicol* (antibiotic) *for 7 to 10 days"* – Farmer 17).

Some farmers reported using sedatives to make the sow calmer after farrowing (*"I make a medicine for the sow when she farrows; when she is in agony, she bites the piglets. But it is very little* (medicine), *1 or 2 ml and she already calms down"* – Farmer 14; *"Uh "Distress", you don't know it* (referring to a brand name)? *So, at farrowing, they get stressed, then you do the medicine, and she sleeps. She sleeps, and they keep being born. The right thing would be to do it later, but we do it like that"*- Farmer 03).

4.5.5 Abnormal and stereotypical behaviours are inherent to animal production and not a welfare concern

In general, participants did not consider abnormal or stereotypical behaviours frequent nor a relevant problem on their farms. Many participants considered all these behaviours natural and inherent to pig production: (*"If you don't have any of this in a farm, worry about something being wrong. (...) If you don't have cannibalism, tail biting (but you can't have too much!), if you don't have any of this, it's because you don't have any animals. This will always exist in the midst of animals"* – Farmer 59).

Table 12. Frequency of occurrence of abnormal behaviours in the herds according to the participants (n=44)

	Frequency (%)			
Behaviour	Always	Sometimes	Rarely	Never
Fighting	36	45	18	0
Bar biting	30	22	18	30
Belly-nosing	16	20	25	39
Tail-biting	9	36	46	11
Dog-sitting (sows)	7	18	30	45

Source: Author

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According to the participants the most frequent behavioural problem was excessive fighting, while for many belly-nosing and tail biting were not present or rarely observed (Table 12). Tail biting worried 11% of participants, given that it interferes with the productivity of the herds (*"Tail biting for sure, that's a doomed pig. He will always have inflammation, pus. If he's bitten when he's tiny, he will always have inflammation"* – Farmer 50). Yet, belly nosing and fights were considered to be of little relevance (*"…very little, but there are always two or three crazy piglets that need to suckle"* – Farmer 22) or natural to the species (*"They start playing and end up fighting, I don't know, like siblings"* – Farmer 16).

Participants had a similar indifference about abnormal or stereotypical behaviours of the sows. Only 33 of the farmers acknowledged seeing sows sitting in a dog position in their farms. The majority (61%) did not know the causes of the behaviour; with some participants pointing out sow genetics (12%), discomfort or pain (9%), or a learned habit (9%) as explanations. Likewise, some participants (30%) did not report bar biting in their sows ("Here you don't see that anymore, but a few years ago it was quite common. I don't know why they did that, I thought it was genetic, but I don't know" – Farmer 17). Yet, others (30%) identified it as always present.

Participants often associated the occurrence of abnormal and stereotypic behaviours with nutritional or climatic failures (Table 13). According to farmers (69%), the leading cause of tail biting behaviour was a nutritional deficiency, more precisely lack of protein in the diet. They also associated belly-nosing with hunger, or lack of nutrition due to low quality of the weaning diet (*"It is common to happen at weaning, this is nutritional. Or because the first diet leaves something to be desired, like little milk in the feed"* – Farmer 18). Some identified separation from the sow at weaning as a possible cause for the belly-nosing behaviour (*"I don't know if it is that they miss the mother, or if it is a tantrum"* – Farmer 34).

Most participants (45%) did not know or did not like to provide an opinion on why this behaviour occurred in the sows. However, others associated the behaviour with hunger or anticipation of food (36%); and a few (19%) with discomfort and pain, mainly in the pre-parturient period.

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Table 13. Causes of abnormal or stereotypical behaviour according to participants.

Behaviour	Reasons	n (%)
High frequency of fights (n=38)	Mixing of pigs of different origins	16(42)
	Nutrient-poor foods	9(24)
	High stocking density	10 (26)
	Others	3 (8)
	Early weaning	0
	Boredom	0
Tail-biting (n=36)	Nutrient-poor foods	25 (69)
	Temperature variation	4 (11)
	Stress	3 (8)
	Others	4 (11)
	Early weaning	0
	Boredom	0
Belly-nosing (n=20)	Hunger	5 (25)
	Nutrient-poor foods	5 (25)
	Weaning (absence of mother)	5 (25)
	Others	5 (25)
	Boredom	0
	Temperature variation	0
Dog-sitting (n=33)	Do not know	20 (61)
	Genetic causes	4 (12)
	Discomfort/ Pain	3 (9)
	Learn the behaviour from other sows	3 (9)
	Others	3 (9)
Sows bite bars (n=33)	Do not know	15 (45)
	Hunger	12 (36)
	Discomfort/ Pain	6 (18)
	Genetic causes	0
	Others	0

Source: Author

4.5.6 Drivers of change

The main motivator for changes appeared to be demands from the industry. Farmers working for integrated companies or cooperatives explained that they were required to meet

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specific standards (*"One thing we have been hearing about animal welfare, especially from cooperatives and integrators, is that they want to end crates and turn all of these into group pens"* – Farmer 22; *"We have a project to make the entire system "animal welfare" (...) ... for us to keep working, we need to go that way, if not, there is no way"* – Farmer 44). Some farmers showed dissatisfaction towards what they saw as unreasonable demands from retailers or integrators (*"The guy who invented this did not step on a farm. ...he never mixed 60 sows in a pen just to see what happens"* – Farmer 33), even when acknowledging that they would meet the demands in the future (*"There is someone who creates the rules regardless of whether I am satisfied with them or not. It is the same as the issue of sows; I do not believe that putting the sow in a pen makes them calmer. But if we want to stay in the market, we have to follow the rules"* – Farmer 9).

Some farmers indicated that financial incentives for quality of production would be an important motivator or even a requirement for them to make improvements on-farm that benefit pigs' welfare (e.g., *"There is a lot to be changed in my farm, if I were to receive a label I would need to change everything around, improve the fences, I would have to improve ventilation, use less antibiotics. But for that, I would need to have an incentive, be paid more. If not, it doesn't work."* – Farmer 02; *"I would have to build housing for group gestation. But today, there is no bonus; the cooperative does not pay for group housing."* – Farmer 42).

Farmers did not see a relationship between Brazilian consumers and demands posed by the industry and did not consider consumers as essential drivers of changes towards improving pig welfare *("I don't think so… they don't follow it, they don't know what happens"* – Farmer 44). In general, they had negative attitudes towards consumers, and many farmers suggested a disconnect between urban consumers and the farming environment *("...they don't even know where this is coming from. We* (farmers) *know"* – Farmer 29; "… *they don't even want to know who is raising them ... they don't even know how it works, they've never been on farm, and they don't know how to raise a pig"* – Farmer 01; "*Last year we worked only in red, and I didn't see anyone in the media saying "poor farmers". They just say, oh, you have to produce cheap food. And let farmers work 24 hours a day."* – Farmer 37). Other participants accused consumers to be solely interested in quality or the price of products ("…*they just buy,*

they don't look at the label or the brand. If it's cheap they're buying it, and that's wrong" – Farmer 50; "The NGOs care. Do you think they (consumers) will know where meat comes from? They just want to know if it has quality ... and if it has a label showing that there has been inspection….they don't even want to know where it comes from." – Farmer 62).

Some participants (22%) considered that there was a niche of consumers concerned with animal welfare, linked to NGOs movements, the trend for consumption of natural foods, or veganism (*"I think nowadays they are a little more concerned. ...it does not mean that it is a fashion, but this fitness fashion, more vegan people, more concerned with nature, I think they are paying more attention to this side: animals, torture and other things"* - Farmer 25). Some expressed their negative attitudes towards animal welfare ("*A portion* (of consumers) *is very concerned about it. It is the "animal welfare people*, *who are just like that, who think of the case of tail docking, that the piglet will suffer. This is a fallacy; it is a lie"* – Farmer 57).

4.6 DISCUSSION

Animal welfare is a complex concept and, as such, researchers often dispute how to best portray the different angles involved (BROOM, 1991; FRASER et al., 1997). For the pig farmers participating in this study, it was no different. They identified all the dimensions (affect, biological functioning and naturalness) that impact the welfare of a pig on a farm. However, their social reality, industry demands and available advice seem to have pushed farmers to perceive their range of action as limited to biological and environmental changes that might affect welfare. Stress in the pigs' life, as well as in their own lives, seemed normalised, even desensitising them to what should be read as abnormal. Thus, we observe a cognitive dissonance among attitudes, beliefs and behaviours towards animal welfare in this community, with negative consequences for the health and welfare of the animals, which were commonly alleviated by routines that relied on frequent use of medication, including high dependence on antibiotics. Expressions of social alienation and social isolation in the production chain were common voices among the participants in this study. This adds to the farmers' inability to see alternatives as viable solutions that could ameliorate their dissonance and improve the lives of

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the pigs they cared for, as well as their own lives (e.g., positive financial and environmental effects of reduced drug use).

4.6.1 Attitudes towards pigs' capacity for sentience and intentions to improve animal welfare

Farmers' attitudes towards pigs' capacity for sentience were generally positive, but this was not reflected in concerns about animal welfare or intentions to modify the production system. This contradiction between farmers' moral values and attitudes has been discussed by others (BERGSTRA et al., 2015; PEDEN et al., 2020). Many farmers thought that their farms already provided good standards of animal welfare. Although all participants believed that pigs are capable of feeling pain, they did not mention any intentions to control pain during management procedures. Like Canadian farmers (SPOONER et al., 2014) the farmers in this study considered their practices to be acceptable, necessary, or the pain unimportant. Thus, farmers were sympathetic to the pain of the animals but did not show empathy, in that they did not try to avoid or minimise the pain. According to FOX (1985), sympathy and empathy are distinctly different phenomena. Sympathy implies the sharing of another's emotions, such as sadness and anguish, and involves feeling pity towards another's experiences of suffering. Empathy, on the other hand, involves more than pity, because it permeates the experience of another's pain and entails having the ability to understand another individual's emotion or sensory state and being able to have a painful experience through the pain of another person or animal (SINGER et al., 2004). Sympathetic concern can be volatile, whereas empathic concern involves an objective, ethical and emotional understanding (knowledge) of animal behaviour or suffering. It is from this understanding that action, compassion and responsibility emerge (FOX, 1985).

Lack of empathy was also demonstrated in the normalisation or desensitisation towards stereotyped behaviours in the pigs. Farmers in general underestimated the occurrence of abnormal and stereotyped behaviours discussed during the interview. Belly-nosing, which can indirectly affect the development of weaned piglets (WIDOWSKI et al., 2008), was considered irrelevant. Tail biting was the abnormal behaviour farmers considered most relevant;

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even so, most considered it inherent to pigs and the production system. Often, not recognising the problem or underestimating its importance is a reason for not adopting preventive measures, as shown in the case of lameness in dairy cattle (OLMOS et al., 2018). On the contrary, perception of aggression as a problem was related to British and Irish pig farmers' willingness to implement strategies to reduce it (PEDEN et al., 2019).

In our study, farmers showed an explicit contradiction between their beliefs and behaviours regarding the suffering of pigs and their motivation to adopt changes to reduce it. Although some study participants described feelings of discomfort about performing painful practices, this was not disruptive enough to counter behaviour traditionally established in the community. Cognitive dissonance is explained as a mental discomfort, triggered when two or more conflicting ideas or beliefs are sustained simultaneously; as people seek internal consistency or harmony, the dissonance is reduced by triggering social-physiological coping strategies (FESTINGER, 1962). The inconsistency between beliefs and behaviours can be explained through the theory of cognitive dissonance (FESTINGER, 1962). Many painful practices identified in our study (castration, teeth clipping and grinding, and tail docking) are socially accepted in the farming community (D'EATH et al., 2016; TUYTTENS et al., 2012; VALROS; BARBER, 2019), and seem anchored in the life experience of the local community (CARDOSO et al., 2016). Belonging to a group that shares knowledge acquired through socially learned practices produces stagnation and limits the proposition of changes (BASSI; et al. 2019).

All practices that we presented during the interview as possibilities to improve welfare or prevent abnormal and stereotyped behaviours, such as environmental enrichment, socialisation before weaning, or avoiding or reducing social regrouping were considered unacceptable by the farmers. These practices are scientifically recognised and have been proven to be effective (e.g.,D'EATH et al., 2016; PEDEN et al., 2018). However, this information seems to remain inaccessible to farmers, confirming similar results with dairy farmers in the region of the study regarding dehorning (Cardoso et al., 2016) and lameness (OLMOS et al., 2018). This implies ineffective communication between the scientific community, local advisors and farmers (OLMOS et al., 2018; PEDEN et al., 2018; VALROS; BARBER, 2019).

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Rather than technical information, community led hands-on experience may speed change within a farming community (WINDER et al., 2018). For example, in general, the attitudes towards group housing for gestating sows were negative among the participants, the exception being those who already were adopting the system. Likewise, some of the farmers that weaned at 28 days showed positive attitudes towards increased weaning age. Others have shown that successful experience with new practices may lead to more positive farmers' attitudes (ALUWÉ et al., 2015; SCHUKAT et al., 2019; VALROS; BARBER, 2019). Here farmers with an entrepreneurial mindset found it easier to break societal norms/structures and dared to explore new avenues to improve their practice as farmers. This mindset is often dependent on their ability to see themselves as competent and with hope in the future (e.g. future generations to pass on the farm, better prices) (BULLER et al., 2018; FRUSCALSO; ANTILLÓN; HÖTZEL, 2017; MEIJBOOM; STAFLEU, 2016).

4.6.2 Farmers' understanding of animal welfare

We identified two key components of the social representation of animal welfare of these farmers – one biological and one economic. The first captures a subjective concept shared by many participants that animal welfare would equate to giving animals what they need for their survival, but not necessarily a life worth living. A similar focus on biological functioning and the living environment has been reported for intensive pig farmers in different countries (e.g., BENARD; BUNING, 2013; KLING-EVEILLARD et al., 2007; SPOONER et al., 2014). Most farmers believed that avoiding disease (e.g. diarrhoea) and having productive performance is proof of high animal welfare, which is a widespread view among farmers and stakeholders in the livestock industries (BENARD; BUNING, 2013; HÖTZEL et al., 2018). Such limited conceptualisation of animal welfare precluded farmers from making associations between good health and the animal's ability to express a full behavioural repertoire. It also prevented them from viewing abnormal behaviours as problems and forms of management that give pigs more than the bare essential for survival as acceptable.

The economic element was expressed in negative attitudes towards effecting changes to improve animal welfare, underpinned in a shared perception that improving animal welfare

required investments that would not be repaid. Some farmers referred to animal welfare as part of a technological package imposed by the industry, and not necessarily legitimate. One example discussed by several farmers was group gestation housing, which many considered unnecessary or even detrimental for the sows' welfare, given the increased risk of fighting leading to sows' stress, a concern also raised by some Canadian farmers (SPOONER et al., 2014). Farmers in many countries consider costs and investments as the main deterrents to implementing improvements in animal welfare on their farms (Brazil: BORGES et al., 2019; Germany: SCHUKAT et al., 2019; China: SINCLAIR et al., 2019; The Netherlands: BERGSTRA et al. 2017; Hungary: MOLNÁR; FRASER, 2020). Additionally, it has been suggested that in many cases, the types of changes demanded to improve farm animal welfare may not correspond to the wishes and interests of society and the farmers (BERGSTRA et al., 2017; YUNES et al., 2018) perhaps turning the investment into losses (WEARY et al., 2016).

Farmers considered diarrhoea the most critical welfare issue among the scenarios presented, possibly because it is directly related to production losses and increased production costs (KAUPPINEN et al., 2012). Although farmers agreed that stress is a predisposing factor for the occurrence of diseases, they did not make direct associations between stress in their pigs and health issues. Nor so to their need to use antibiotics consistently along with other drugs for several ailments/situations on-farm (see farrowing management practices reported). Yet, they more clearly saw opportunities to improve health with biosecurity measures. Indeed, biosecurity is an essential element in reducing antibiotic use on-farm (POSTMA et al., 2017). Still, management practices such as weaning at an older age, decreased stocking density, providing environmental enrichment and pain mitigation are also good alternatives to improve health. They act as preventive measures by reducing stress and strengthen the pig's immune system and thus may reduce health problems and the need for antibiotics.

4.6.3 Farmers-consumers disconnection

Farmers saw consumers as distant and unfamiliar to farming and, at times, even as a threat to their way of earning a living, thus not influencing their decisions explicitly. Like Dutch farmers in the study reported by BENARD and BUNING, (2013), many farmers described

consumers as greedy, uninformed or uninterested in how pigs are raised and how hard the lives of farmers can be. Some expressed frustration at the expectations of "unrealistic consumers" or pressure from third parties with conflicts of interest.

Farmers' focus on biological and environmental aspects is also in contrast with lay citizens in many parts of the world (SATO et al., 2017; WEIBLE et al., 2016; YUNES et al., 2017), who consider freedom to move and the ability to perform natural behaviours essential components of pig welfare. However, these different views regarding what constitutes good welfare do not arise from different values regarding the animals between these two stakeholders. Farmers' conceptualisation of animal welfare led them to normalise stressful practices and to blind themselves to the pain and stress of the pigs for whom they had sympathy. The inability to identify some production practices and abnormal behaviours as problems and the inability to solve them may emerge as cognitive dissonance. Yet, the worried citizens who see themselves as pushing for better production systems may read this as a lack of farmer empathy or total ignorance at its best, further creating mistrust between the stakeholders deepening the divide between farmers and consumers.

Still, a portion of farmers recognised that some consumers are interested in animal welfare and that this is an important segment to be considered. Some research indicates that Brazilian citizens are concerned with many issues present in the farms visited, such as the use of antibiotics, painful procedures (HÖTZEL et al., 2020; YUNES et al., 2019) and housing that limits pigs' freedom of movement (YUNES et al., 2018). Citizens' social representation of animals has changed over time (COOK, 2015), with many citizens reducing the consumption of animal foods, buying 'more natural' foods and even adopting more radical changes in eating habits, such as veganism (HEISE; THEUVSEN, 2017; ROMÁN et al., 2017; VALENTE et al., 2019). Following an international trend, retailers and industry in Brazil are making commitments to improve pig welfare (YUNES et al., 2017). Findings from this study suggest that farmers may not be sufficiently informed or engaged to allow them to promptly respond to consumers and to commitments made by these stakeholders, which can pose a severe economic risk for farmers.

1 Article publishing in the journal Animal: https://doi.org/10.1016/j.animal.2020.100154

4.7 CONCLUSIONS AND MOVING FORWARD

Although we identified many management and animal indicators of poor welfare (e.g., use of painful and stressful management practices and use of environments that limit the expression of natural behaviours), most farmers were satisfied with animal welfare standards at their farms. They saw no justification for further investments to improve it. These perceptions are aligned with the farmers' understanding of animal welfare, mostly comprising good biological functioning. Likewise, any changes they would consider making to improve animal welfare were related to productivity, such as biosecurity, climate comfort and infrastructure, and many explained their perception that improving pig welfare is costly. Farmers are considered gatekeepers of the welfare of the animals under their care. To fulfil this role, they may need some autonomy, which seemed lacking in this group.

Increasingly, farm animal welfare is best described as a One Health/One Welfare issue (BULLER et al., 2018). This approach forces us to understand and accept the complex interactions between human welfare, animal welfare and environmental issues that are related to animal production. Firstly, many measures proposed to improve pig welfare conflicted with the farmers' perceived practical and economic realities, and were not supported by their knowledge and technical skills. Secondly, to maintain pig health in such stressful environments, farmers relied on pharmaceutical drugs, especially antibiotics. Thirdly, farmers reported living a stressful life and feeling at the mercy of "irrational, greedy or selfish consumers", demanding companies and unfair rules. Altogether, the findings of this study indicate that, to improve pig welfare in intensive production systems, there is a need to (re)connect the different human, animal and environmental interests.

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5. WAITING FOR MARKETS TO CHANGE ME – VIEWS OF ANTIBIOTIC USE AND ANTIBIOTIC RESISTANCE BY HIGH-STAKEHOLDERS OF THE BRAZILIAN PIG INDUSTRY

5.1 HIGHLITS

- Antibiotics are the foundation of intensive pig farming whose support pillars are social, health and economic.
- Participants identified more barriers than motivations to adopt measures of prudent use of antibiotics in Brazil.
- Participants perceived the preventive use of antibiotics as indispensable by professionals, due to the hygienic-sanitary conditions of the farms.
- Not all professionals believed in the responsibility of agriculture and livestock for AMR.
- The main motivator for prudent AMU in pig farming were foreign markets; internal consumers and AMR were weak motivators of changes for these professionals.

5.2 ABSTRACT

Brazil is the 4th largest pork producer in the world and its participation in the international meat market may put pressure on the pork industry to adopt strategies for the rational use of antibiotics in the future. In order to explore the knowledge and attitudes of high-level professionals in the Brazilian pig production chain, we conducted 32 in-depth interviews addressing the topics of use of antibiotics in pigs, policies of rational use of antibiotics (AMU), antibiotic resistance (AMR), role of consumers and the relationship between the pig welfare and antibiotics. The majority of the participants believed that AMU is inappropriate and abusive in pig farms. However, their attitudes were mostly negative to a restrictive AMU scenario within the context of Brazilian pig farms. The barriers identified were economic, health and social. The participants considered preventive AMU as an acceptable resource, given the unsatisfactory conditions of management and biosafety in pig farms. In addition, in the view of these professionals, antibiotics were considered essential for the production of cheap food. For most participants, consumers were not sufficiently informed about AMR and AMU in pig production, and therefore should not be considered in the discussion. Participants believed that AMR was more associated with the inappropriate use of antibiotics in human medicine than in intensive livestock. The foreign market was considered to be a more relevant driver of change in AMU than the risks of AMR to people, or pressure from Brazilian consumers. In conclusion, the participants showed little motivation and autonomy to change their behaviour regarding AMU in pigs. This was underpinned by economic, sanitary and social barriers that helped maintain the status quo of AMU, and employment and income relationships of these stakeholders. However, we believe that the responsibility for the rational use of antibiotics is collective, which requires multidisciplinary collective policies, defined in a clear and unisonous way, to lead to concrete actions in the fight against AMR in Brazil.

5.3 INTRODUCTION

Public policies for the prudent use of antibiotics have been discussed and implemented in several countries to respond to the threat of bacterial resistance to antibiotics (AMR) (BVA,

2019; FAO; DVFA, 2019; WHO, 2015). The complexity of AMR transmission requires collective efforts (KENYON, 2020) in order to guarantee sustainable interactions between people, animals and the environment and the political and social realities of nations (HERNANDO-AMADO et al., 2019; ROOPE et al., 2019). The One Health initiative, which is part of the Global Action Plan to combat AMR (FAO, 2016), encourages the development of systemic strategic plans that involve connections between human, animal and environmental health (HERNANDO-AMADO et al., 2020; ZINSSTAG et al., 2011).

Although the resistance process is natural defence mechanism of bacteria, it can be intensified by the misuse of antibiotics for humans and animals. Inappropriate use of antibiotics in human health is a powerful inducer of AMR; additionally, the volume of antibiotics used in livestock has an even greater potential for the spread of these bacteria, especially in the environment (VAN BOECKEL et al., 2019; WOOLHOUSE et al., 2015). AMR transmission can occur through direct contact with contaminated animals and food, which puts farm and slaughterhouse workers at risk (BENNANI et al., 2020; LEE et al., 2020; SHIGEMURA et al., 2020), or via contaminated food and the environment (BENNANI et al., 2020; WOOLHOUSE et al., 2015). Several studies detected the presence of resistant bacteria genes in pig manure, sewage, urban water reservoirs and in food (HE et al., 2016; HONG et al., 2020; SABRI et al., 2020; TYRRELL et al., 2019). Thus, the restriction of antibiotics in farm animals may contribute to the decrease of these resistant bacterial genes (NOBREGA et al., 2020).

About 70% of the volume of antibiotics produced in the world is used in intensive livestock production, mainly in sub-therapeutic doses to promote weight gain or prevent diseases in herds (O´NEILL, 2016). Pigs are vulnerable to infections due to their short and intense life cycle, associated with unhealthy and stressful rearing conditions (NAKOV et al., 2019). A common strategy to prevent diseases is the use of antibiotics, often in place of preventive practices (BOKMA et al., 2018) and, for this reason, pigs and broilers are the production systems that most use antibiotics in sub-doses (VAN BOECKEL et al., 2015). Evidence of the presence of the mcr-1 gene in an E. coli plasmid in food in China (LIU et al., 2016) has triggered the AMR alarm worldwide; this led several countries, including Brazil, to ban the use of colistin as an additive in the food of farm animals.

Brazil is the fourth largest pig producer in the world and the export of pork is an important activity in Brazilian agribusiness. The public health emergency involving AMR could put pressure on countries that export agricultural products to adapt to international

requirements for use of antibiotics in the future (WIELINGA et al., 2014). The Brazilian Ministry of Health, together with the Ministry of Agriculture and other entities, developed a program to start discussions on the use of antibiotics in Brazil, PAN-BR (Brasil, 2018). Part of program refers to the control of the use of veterinary antibiotics and health education for stakeholders in the animal production chain.

For any strategy to work, a practical and situated knowledge of AMU in the productive chain is needed to plan which activities to include and how, where bottom up approaches are more effective than top-down (CAUDELL et al., 2020). Qualitative research can help to capture elements to better understand the social context in which the use of antibiotics and AMR are involved in pig farming. In addition, exploring the attitudes of professionals in the pig production chain can help to identify barriers for the implementation of public policies and identify strategies that encourage changes in behaviour regarding the rational use of antibiotics (PEARSON; CHANDLER, 2019). The objective of this study was to explore the knowledge and attitudes of professionals in the animal production chain about the use of antibiotics for pig, AMR, animal welfare and measures for the prudent use of antibiotics in Brazil.

5.4 MATERIALS AND METHODS

This work is part of the research project “Knowledge and attitudes of Santa Catarina's pig farming on antibiotics, bacterial resistance and animal welfare” carried out by the Laboratory of Applied Ethology at the Federal University of Santa Catarina - LETA-UFSC. This particular study followed a qualitative approach to obtain a detailed account of stakeholder views on antibiotics and animal welfare acquired through in-depth semi-structured interviews. The concept of AMR covers a variety of drugs. However, the focus of this study is antibiotics, due to the amount of use and the importance that these drugs have in the pig production chain. This study was approved by the Human Research Ethics Committee of the Federal University of Santa Catarina (CEPSH / UFSC) under decision No. 2.562.764.

5.4.1 Participant recruitment

For carrying out this study, we sought professionals with agricultural training (Veterinary Medicine, Animal Science, Agronomy, Agricultural Technicians) who were linked to the pig production industry. The first participants (informants) were recruited from personal contacts of RAG, who is a veterinarian, trained in 2004 by the Federal University of Pelotas

and professors employed at the Instituto Federal Catarinense since 2010. The other participants were indicated through names suggested by the informants or by contact with the official entities or bodies to which the participants were linked.

The interviews were conducted from April 2018 to July 2019. Participants were interviewed by RAG, in person, via telephone or by videoconference, according to the availability of the participants, in Brazilian Portuguese. The participant could speak freely about the topics covered in the interviews, which lasted between 30 minutes and 2 hours. In accordance with the CEPSE-UFSC regulations and the current legislation (Resolution 466/2012) for research work with humans, the participants received a Term of Free Consent and Clarification (TLCE). This term contained all the information about the research and its responsible persons and about the instructions regarding the participants' rights. The FICFs were sent by e-mail or delivered by hand during the interviews.

Participants were 32 individuals (69% were men and 31% women) that held among 3 and 30 years of professional activity, of which 69% were veterinarians, 22% animal scientists and 9% other professions. They belonged to different sectors of the pig production chain, as described in Figure 1. Information on the use of antibiotics in pig farming was gathered from some participants that were directly linked to the pig production chain. The group included veterinarians from the animal health sector, agricultural technicians and extension veterinarians, veterinary sales representatives, animal nutritionists, agricultural inspectors, researchers and university professors. Some of them had coordination functions and represented important entities and associations in the pig production chain. To maintain the participants anonymous, we numbered them sequentially from 1 to 32 and did not specify their profession or role with the animal sector. The characteristics of these groups and how these stakeholders relate to each other are described in the section “Social pillar”.

5.4.2 Script interview

The central themes discussed with the participants are described in Table 14 (Appendix D). At the end of the interviews, we presented the participants with a hypothetical scenario of restricted use of antibiotics in line with international models of rational use of antibiotics. Participants should give their opinion on the feasibility of this scenario within the Brazilian pig productive context and point out measures they judged necessary to adapt the production chain to such scenario.

We asked some questions to characterize the intensive pig breeding system that helped us to understand the production chain and to define issues in other projects with farmers (ALBERNAZ-GONÇALVES et al. 2021b, 2021a).

5.4.3 Data analysis

Data analysis was done with the aid of the NVIVO 10 software, using a thematic analysis approach (see BRAUN AND CLARKE, 2006) to provide a "rich and detailed, yet complex account of data. All interviews were transcribed in Portuguese verbatim by the first author of the study. Closed responses were organized with the help of Microsoft Excel and summarized using descriptive analysis. The transcribed text was read several times thoroughly by RAG and MJH and coded in central themes. Codes were initially identified to capture the salient features of the dataset by RAG. Through interactive discussion, codes were identified and developed into themes by the tree authors. Disagreements were discussed until consensus was reached among all authors. Representative phrases of themes were selected for final discussion and presentation of were translated by MJH.

5.5 RESULTS

5.5.1 Antibiotics are the foundation of pig production

The participant's reports pointed to antibiotics as material infrastructure of pig production and that infrastructure consists of three pillars: social, health and economic. Respondents trusted antibiotics and credited them for the success in the production rates and health control of pig herds. They considered these drugs as an essential part of a technological package aimed at productivity (P17a, P1a).

We have divided this section into two subsections. In the first we describe the social, health and economic pillars that are supported by antibiotics and examines how the social actors in the production chain are inserted in this context. In the second one, we analysed the industry's dependence on antibiotics and the consequences of antibiotic restriction policies for the Brazilian pig industry, in the opinion of the participants.

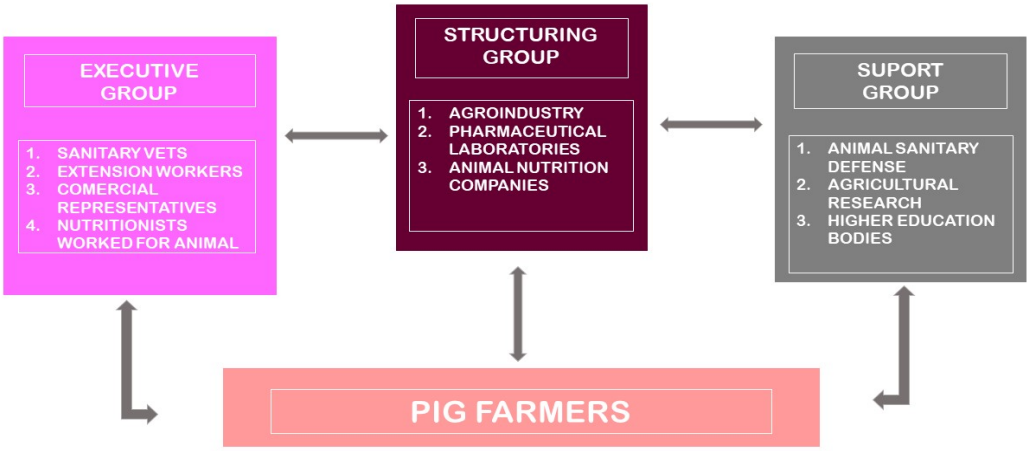
Social pillar - The connection between the actors in the pork chain

In the social pillar, we identified the main social actors in the pig production chain and their relationship with antibiotics. Figure 4 demonstrates graphically the role played by these

actors and their interactions. Based on the participants' report, we defined the animal production chain and its social relations in three social/interest groups (structuring, executive and support).

The **structuring group** was made up of the most stable elements in the production chain, which had the greatest influence on the other stakeholders. Agroindustry, the pharmaceutical industry and animal nutrition companies belonged to this category due to their level of importance and prestige. These economic groups maintained a cooperation network strengthened by antibiotics. Pharmaceutical laboratories supplied antibiotics and nutrition companies supplied nutritional inputs, both essential for the production and productivity of agroindustries. All these groups profited and employed professionals to carry out the production practices that met their economic demands. They determined the rules of creation, through the economic subordination of professionals and farmers and the influence on political groups that defined state and federal laws. Thus, the relationship between the structuring agents was one of mutual bolstering and preservation of the production chain. We were unable to get representatives from this stratum willing to participate in our study, although we invited them. All the information about this group arises from the reports of individuals in the other two groups.

Figure 4. Organization of the pig production chain and the relations between the stakeholders.



Source: Author

The **executive group** of the production chain included professionals who carried out the impositions dictated by the structuring group. Professionals with higher or technical training who worked as employees of companies or as self-employed professionals linked to structuring groups at some levels were part of this group. A total of 53% of the participants in this study belonged to the executive group of the pig production chain and were identified in the text as veterinarians, health professionals, field professionals (extension workers), nutritionists and commercial representatives.

Sanitary veterinarians and field professionals were part of the technical staff of the agroindustries. It was up to the sanitary veterinarians to define the antibiotic protocols to be adopted in the herds. These protocols were defined through negotiations with commercial representatives linked to the pharmaceutical companies (P31a). Nutritionists worked for animal nutrition companies that provided services to agroindustries, for individual farmers, feed factories and agribusinesses. The agroindustries' nutritional programs were defined among nutritionists, veterinarians and technicians. The role of extension workers or field professionals was executing the protocols defined by the veterinarians and nutritionists and of supervising the practices adopted by the farmers (P30a).

The extension workers maintained direct contact with the farmers and constituted the main link between the farmers and the agroindustries (P26a). The commercial representatives of the pharmaceutical laboratories had contact with all groups through the sale of medicines and agricultural inputs. Several of these veterinarians provided free technical assistance to those farmers who bought their medicines (P4a).

We identified two types of relationship in which the executing agents were inserted. The executive agents maintained a subordinate relationship or direct financial link with the structuring agents, through employment or income from the sale of their products. Among themselves, on the other hand, they maintained a cooperative and partnership relationship as they did not necessarily have direct economic ties.

The **support group** was made up of animal sanitary defence professionals, agricultural research and higher education bodies. 47% percent of respondents belonged to this layer of the production chain. Animal sanitary defence group developed the rules and inspected food factories, slaughterhouses, and commercial warehouses. In addition, it participated in the preparation of technical normative instructions that regulated the production of food of animal and vegetable origin that supplied the domestic and exports markets. State, private or municipal

entities indirectly influenced the decisions of the production chain in different ways Agricultural research was related to the three components of the structuring group (i.e., the agroindustries, nutrition companies and pharmaceuticals) and to farmers via scientific research that was of interest to these groups. Finally, higher education institutions although responsible for the training of professionals have less direct involvement and influence on the pig production chain than the agricultural sanitary defence and research agencies. Higher education institutions also carried out research, directly or indirectly associated with the above-mentioned economic groups. All these institutions (i.e., research, sanitary defence and higher education) had a formative and guiding feature and role since the main recommendations that lead professionals (executors), and farmers are provided by them. We represented this relationship on the graph (Figure 4) more externally to the others because of its influence, even if indirect, upon all the other stakeholders.

Sanitary pillar - "We need antibiotics because our environmental conditions are bad"!

One of the main concerns expressed by the participants regarding the restriction of antibiotics referred to the potential difficulty in controlling the diseases of the herds. It is important to note that the participants' insecurities referred to the preventive use of antibiotics and not to their curative use. In addition, this concern came mainly from the participants of the executing group (P15a). Although participants recognized the use of preventive antibiotics on farms as abusive (P32a) they considered this an acceptable resource to deal with stressful situations (P1b). Participants believed that hygiene conditions and biosecurity of the farms was below what is necessary to allow the preventive use of antibiotics to be dispensed with (P26b, P4b). The reduction of the prophylactic use of antibiotics was considered a threat to the maintenance of the health of herds, given the inappropriate conditions of management and health (P30b). For some, this could result in an increase in the use of antibiotics, due to the increased use for curative purposes (P20a). Importantly, despite being resistant to the possibility of AMU restrictions, the participants were clear about what measures would be necessary to adopt rational use strategies (P15b).

Economic pillar - "It is cheaper to raise pigs using antibiotics"!

Economic concerns raised by of the participants referred to the loss of productivity in the absence of growth promoters, the increase in costs in the case of restrictions to AMU, and

losses in income arising from the sale of antibiotics. Growth promoters were seen as important players with an essential role for producing cheaper pork. In general, participants expected that a ban of AMU for growth promotion would reduce productivity on farms (P15c). Participants linked to agri-businesses and nutrition companies (health veterinarians, field technicians and nutritionists), stated that international markets were pressuring agribusinesses to abandon the use of growth promoters (P30c). Many participants considered the withdrawal of growth promoters as a lost battle. Some of them believed that the ban would open space for the development of new pharmaceutical additives to replace antibiotics (P1c). For some, producing with reduced AMU cost more and the Brazilian market would not absorb an increase in the price of meat (P6a). Likewise, the low cost was seen as condition for competition in international markets (P8a).

In the opinion of the participants, changes in the pig chain would be necessary such as to improve health and animal welfare for reducing the use of antibiotics on farms. Suggestions for changes included the renewal of the Brazilian technological park, appropriate financing lines and government programs to assist farmers and agro-industries in this transition period. Most changes were considered costly and financially disadvantageous for farmers and agro-industries (P9a). A key point addressed by stakeholders of all groups was that achieving the levels of pig welfare to reduce current AMU required investments, but there was no expectation of financial return (P12a). Antibiotics were described as part of the infrastructure to ensure animal welfare (P8b), which supported concerns that reducing preventive AMU would be detrimental to the pigs' welfare (P14a).

Yet, some believed that the current high AMU resulted from low levels of pig welfare on farms, and that reducing AMU required improving the welfare of pigs (P9b). All the stakeholders described animal welfare with a clear emphasis on production and profit, and the concept of animal welfare expressed by the participating stakeholders was centred in health, thermal comfort and productivity (P6b, P5a).

Finally, the employment and income relationships arising from the sale of antibiotics were described as an important part of the economic pillar. Some participants reported a relationship of dependence of veterinarians, agronomists and animal scientists with pharmaceutical laboratories, through jobs as commercial representatives or from the sale of veterinary medicines (P14b, P10a).

5.5.2 Pork chain ambiguities in the AMU and AMR relationship and their impact on Brazilian consumers

Part of the participants showed scepticism regarding the link between AMR in humans and AMU in animal production. There were more expressions of concern about the damage caused by the withdrawal of antibiotics for preventive use than about possible risks to public health from AMU. Some felt that it was necessary to have more scientific evidence and studies to discuss the risk of livestock for the spread of AMR. Without this evidence, some argued that it would not be correct to impose restrictions on the use of veterinary antibiotics (P8c, P15c). However, others, who accepted that the relationship between AMU in livestock and AMR, advocated for a stricter conduct in relation to the purchase and sale of veterinary antibiotics (P9c).

The lack of information or interest on AMR by Brazilian consumers was used to reinforce the narrative that the costs of changing AMU would not be acceptable (P23a, P17a). However, some participants acknowledged that there was a segment of public concerned with AMU and food safety in products of animal origin and that this should be considered. Although they viewed it as a specific market niche with greater purchasing power and that they would not represent most of the Brazilian population (P18a). Others saw a trend for change in consumer behaviour and a rise in new generations of consumers more informed with habits and quality requirements different from the previous generation (P1d).

5.5.3 Antibiotic dependence: Changes in the use of antibiotics can collapse the pig production chain

Participants demonstrated predominantly negative attitudes towards policies that could restrict antibiotics in pig farming in Brazil; 69% of them considered that these restrictions would have disastrous impacts on the pig production chain (P30d). Even the rest (21%), who understood the current AMU use in Brazil as abusive, assumed losses and identified the same barriers (economic, health and structural) in the implementation of these policies as those that were unfavourable. Although sceptical about the effectiveness of a restrictive antibiotic scenario in Brazil, some participants believed that changes would inevitably happen (P17b). Most believed that changes in use and antibiotics would be mandatory and would come under

pressure from foreign markets. As pork exports are important for Brazilian agribusiness, some of them assumed that legislation would meet international requirements and that agro-industries would be forced to adapt (P21a, P5b).

5.5.4 Changing the law is easier than enforcing it

The participants considered that, if Brazil adopted policies to restrict AMU, the starting point should be control of purchase and sale of veterinary drugs (P28a). They understood that the success in the implementation of regulatory measures depended on effective inspection of agricultural houses and other businesses, to be carried out by Brazilian health agencies (P1c, P31b). Participants pointed out that the success of restrictive measures of AMU also depended on training veterinarians and farmers in good production practices and prudent use of AMUs (P21a). Animal health defence professionals reported that governmental animal health agencies were already organizing discussions on the topic and health education was included in the strategies for planning the rational use of antibiotics in Brazil. Some participants linked to the **support group** (researchers and animal health protection) assumed that legislative changes could meet political resistance among parliamentarians related to pharmaceutical groups or by agro-industries and that political impasses could hamper the progress of technical proposals aiming at prudent AMU in the country (P9d).

5.6 DISCUSSION

The results of this study show that antibiotics play a structural function in the pig production chain, far beyond their pharmacological benefits. There is an intricate network of stakeholders who depend on the social and financial relationships that antibiotics provide. These links (financial or not) seemed to underpin the lack of autonomy or motivation of these stakeholders to contribute to making real changes in the use of veterinary antibiotics. For this reason, although the study participants understood the problem of the excessive AMU in pig production, they did not trust the effectiveness of policies to restrict AMU in Brazil. The subtle associations between the different social actors and antibiotics make it difficult for them to perceive the problem. CHANDLER (2019) e KIRCHHELLE (2018) described a structure, sometimes invisible, based on antibiotics.

The barriers raised by the participants to policies restricting AMU show how much the pig production chain depends on these drugs for profitability and job opportunity. We identified

a collective representation among the participants, where antibiotics were viewed and felt as a "magic" or "miraculous" solution to complex structural problems (CHANDLER, 2019). WILLIS and CHANDLER (2019) in their ethnographic work, defined antibiotics as a *"quick fix for care in fractured health systems; a quick fix for productivity at local and global scales, for humans, animals and crops; a quick fix for hygiene in settings of minimised resources; and a quick fix for inequality in landscapes scarred by political and economic violence"*. The use of antibiotics involves economic, political and social factors (MINSSEN et al., 2020) and therefore, the success of public policies to respond to the AMR problem demands social research that explores the engines of antimicrobial resistance.

Even if some participants acknowledged the environmental spread of AMR caused by AMU in pig feed, they did not make a clear connection with human health (and antibiotic resistance which is a public health concern globally). Other authors have demonstrated this type of beliefs among veterinary professionals (EKAKORO et al. 2019; GOLDING et al. 2019). By being more concerned with the economic and productive consequences of withdrawing antibiotics than with the risks of AMR, participants demonstrated low concern with the causes (i.e. poor animal welfare) that may lead to the abuse of AMU. The lack of concern and lack of urgency with the AMR public health problem may explains the passivity of the participants in expecting or demanding changes. By stating that there is lack of evidence regarding the role of livestock on the spread of resistant bacteria, professionals in the pig industry maintain the *status quo* of their practices and defend their "territory" (FORTANÉ, 2019). This perception of low (or lack of) responsibility of the livestock sector transfers the problem to other spheres, in this case, the medical one. The fragmentation of the AMR problem makes it difficult to attribute ownership of the problem, which generates controversies in establishing cause and effect relationships, in the elaboration of regulations, and in the execution of contingency plans (FORTANÉ, 2019).

Believing that Brazilian consumers were not sufficiently concerned (or informed) with AMR and antibiotics, the participants showed disinformation and disconnection with the public. Several studies have shown that Brazilian citizens are increasingly interested and informed in relation to production systems, animal welfare, and in particular with residues of chemical inputs used food production (HÖTZEL et al., 2020; YUNES et al., 2017). Based in the belief that consumers were uninformed, they resisted to establish an honest dialogue with consumers,

including many of the stakeholders that represented important institutions in the supply and inspection of food that are in the position do so.

While most of the professionals in our study acknowledged that AMU in pig production could be considered abusive, there are no official evidence or records of the use of veterinary antibiotics in Brazil that are easily accessible to support this widely held view. In two studies conducted as part of the same research project (ALBERNAZ-GONÇALVES et al., 2021ab) we showed excessive AMU by pig farmers from Santa Catarina, to the detriment of appropriate biosecurity measures, environmental conditions or improvements in animal welfare. Antibiotic prophylaxis can mask symptoms of illness, while allowing the presence of resistance genes in asymptomatic animals (OKELLO et al., 2014).

The view that antibiotics can be used to prevent disease is shared between farmers and professionals in the production chain (ALBERNAZ-GONÇALVES et al., 2021b; COYNE et al., 2018, 2019). A study carried out with medical doctors and veterinarians from low and middle income countries (Ethiopia, India, Nigeria, the Philippines, Sierra Leone and Vietnam) showed that health professionals, although aware of the risks of AMR, preferred to prescribe broad-spectrum antibiotics than to adopt measures of rational AMU (PEARSON; CHANDLER, 2019). Professionals identified in this study as in executive or support group are the main source of reliable information for farmers. Therefore, they must be the first advocates of prudent AMU measures. The establishment of an effective dialogue between these actors is essential, since they play a role as veterinary authorities vis-à-vis farmers (BJÖRKMAN et al., 2021). This dialogue must have a proactive approach, with a unified, unambiguous message, consistent with the reality of these farmers (BJÖRKMAN et al., 2021; KRISTENSEN; JAKOBSEN, 2011).

Many practices and attitudes towards AMU and AMR (ALBERNAZ-GONÇALVES et al., 2021b) and pig welfare (ALBERNAZ-GONÇALVES et al., 2021a) reported by farmers in the companion studies were confirmed and shared by the stakeholders in the pig chain interviewed in the present study. These include the restricted conception of pig welfare and inability to associate animal welfare with the AMU problem, the reliability on AMU as a preventive health tool, and description of antibiotics as part of the material infrastructure that supports cheap pork production. Also, low animal welfare and biosecurity level in pig farms, and easy access to antibiotics, mentioned by stakeholders in the present study as a reason for

abusive AMU, were observed in these two studies. The conflict of interest of veterinarians that make a profit from prescribing antibiotics was reported by farmers in these studies and led to loss of trust in these stakeholders, which undermines their potential to contribute to change in AMU. Altogether, these findings indicate the need for collective actions rather than targeted individual behaviour changes to tackle the AMU/AMR problem (CHANDLER, 2019).

It will be up to the stakeholders of the pig production chain and government institutions to lead the changes to reduce and improve AMU in Brazil. However, the reckless AMU and control of AMR should not be seen only as a problem of individual behaviour of these professionals or the farmers. These stakeholders must be informed about the best production and AMU practices. However, Brazilian and international health agencies need to be involved in a more comprehensive way. As the experience with facing the COVID-19 pandemic has shown, the lack of a universal approach to fight and prevent the disease has cost millions of lives. The response to the threat of AMR depends on collective, systemic and interdisciplinary actions; however, these approaches can be undermined by policies focused on individualized behaviours (CHANDLER, 2019; TARAZONA; CEBALLOS; BROOM, 2019). The lack of a single international conduct in combating AMR has resulted in uneven and conflicting regulatory approaches (KIRCHHELLE, 2018a) that can result in passivity and lack of action ("implementation gap") in public policies on the use of antibiotics (KIRCHHELLE et al., 2020).

5.7 CONCLUSIONS

The participants in this study did not demonstrate autonomy and motivation to demand or participate in the construction or implementation of effective changes in the use of antibiotics in pig farming in Brazil. At the basis for this indisposition, we identified economic, sanitary and social barriers that helped maintain the status quo of AMU, and employment and income relationships of these social actors. However, we believe that the responsibility for the rational use of antibiotics is collective, and only multidisciplinary collective policies defined in a clear and unisonous way can lead to concrete actions in the fight against AMR in Brazil.

6. GENERAL DISCUSSION

In this thesis, we discussed the association between the use of antibiotics and pig welfare in intensive production systems. The main finding of this study was the evidence that the pig production chain is sustained on a foundation of economic, technical and cultural dependence on antibiotics. To deal with the AMR problem it is necessary to recognize that there is a global infrastructure for antibiotics in the context of human and animal health (CHANDLER, 2019), and recognize all the socioeconomic factors that involve AMR (MINSSEN et al., 2020). Multidisciplinary strategies such as One Health and One Welfare can provide a holistic view of AMR and propose combined solutions between different areas of knowledge. The results of this study show that antibiotics play a structural function in the pig production chain, far beyond their pharmacological benefits. Adopting good rearing practices that value pigs' welfare requires training qualified professionals and pig farmers. Policies for the use of antibiotics should provide for continued training of their professionals and agroindustries should seek to disseminate this knowledge among their subordinates.

Economic dependence on antibiotics was evidenced by the employment and income relationships resulting from the antibiotic trade. An important finding of the research was that many veterinarians who provided technical assistance to farmers in exchange for the purchase of medicines and agricultural inputs. Therefore, we can assume an ethical-professional conflict of interests that contributes to sustain the problem of AMR (AARESTRUP, 2012; FORTANÉ, 2019; KIRCHHELLE, 2018a).

Commercialization in agricultural stores, without the need for sales control, favour the indiscriminate use of antibiotics and has also been described in other studies (DYAR et al., 2020; STRÖM et al., 2018). The supply of packages with antibiotics and prescription lists by agro-business without a precise diagnosis also encourages the abusive use of medicines denotes impersonality and a lack of commitment with the farmer by veterinarians. The reports of farmers who identified the inappropriate use of antibiotic suggested an inefficient dialogue between farmers and professionals. We did not capture in the conversations a cooperative discourse between the parties. It is necessary to strengthen the bond between these players through a mutualist and less directive discourse (KRAMER et al., 2017), i.e., farmers and professionals must be seen as allies, and not as competitors.

The need to use antibiotics for prevention and for weight gain indicates technical dependence on antibiotics. Antibiotics were seen as effective tools to control disease and to

enhance the productive indexes of herds. Both farmers and professionals considered antibiotics to be indispensable and responsible for the good productive results of Brazilian pig farming, especially antibiotics used for prophylaxis. One of the main justifications for the use of antibiotics for prophylaxis was related to the biosecurity of the farms. All participants agreed on the importance of adopting best biosafety practices; however, despite these positive attitudes, farm practice was not aligned with the discourse. The reports of farmers and professionals reinforced the understanding that pig farms lacked basic elements of hygiene and disease prevention. The experts were suspicious of the farmers' commitment to adopting these measures on farm, while the farmers themselves said they did not do so because they considered these measures onerous. Similar negative attitudes have been identified in other surveys (DAVID et al., 2020). However, other studies have emphasized the importance of better management and biosafety practices on reducing the use of antibiotics (CAEKEBEKE et al., 2020; RAASCH et al., 2020; STYGAR et al., 2020).

Technical dependency was also linked to cultural ("*tabu*") dependency on AMU. We perceived a pre-established culture among farmers and professionals around the need to use prophylactic AMU, accepted by all as legitimate and immutable. These stakeholders were aware of changes in the use of growth promoters and considered other alternatives to replace antibiotics. However, abandoning prophylactic AMU was unthinkable for them. This materialized in the report of farmers and professionals about a universalized conduct of prophylactic AMU on farms, regardless of the type of link with the agro-industries. AMU was seen as a more practical and more "economical" tool than investing in structural changes (WILLIS; CHANDLER, 2019). In any case, there was always a need for the "magic pill", the idea that the pharmaceutical and nutritional industries will produce other practical and quick solutions to complex management problems.

Although there was an understanding that it was necessary to improve biosecurity, the same was not reflected in improvements in animal welfare. Study participants, although quite diverse, had homogeneous opinions in relation to animal welfare. Most of them emphasized the biological and productive aspects as sufficient to ensure animal welfare and had a greater understanding that animal welfare principles applied to gestating sows mostly, disregarded the affective states and natural behaviours of the pigs. In general, they found it difficult to establish a causal relationship between improving the living conditions of pigs and reducing the need for AMU. We have shown through the literature review that to improve the health of herds and

reduce AMU, it is necessary to integrate the concept of animal welfare as an ally to strengthen the immunity of pigs. A link exists between maintaining good welfare standard/practices and a reduced risk of illnesses, thus good welfare could lead to a reduction of AMU (RAASCH et al., 2020). However, such link is not clear within the Brazilian chain.

None of the groups of respondents (farmers and professionals) considered AMR as an immediate concern for the pig production sector. Even though they were relatively informed about the topic, they did not perceive AMR and AMU in pig farming as a risk to the health of the population and of themselves. The environmental impact caused by the release of pig manure with antibiotics' residues was not mentioned as a risk to public health. All the groups interviewed blamed AMR on the misuse of antibiotics in human medicine, which indirectly exempted livestock from liability and validated the abusive use of veterinary antibiotics. This reactive and denialist stance has also been identified by other researchers and may impair the effectiveness of measures to AMR combat (EKAKORO et al., 2019; GOLDING; OGDEN; HIGGINS, 2019).

In general, farmers and professionals demonstrated demotivation and lack of autonomy to make changes related to animal welfare and AMU. We can assume from the conversations that if there are changes in the Brazilian scenario in relation to animal welfare or AMU they will be top-down. However, we have identified a general disbelief in the effectiveness of restrictive AMU measures in Brazil. Although everyone agreed with the need for intervention promoted by the external links in the chain (political groups, pharmacists, agro-industry and supervisory bodies), they did not trust these changes would happen. We conclude that there is a need for a change of collective thinking in the Brazilian animal production chain through health education, technical training and other training strategies that motivate stakeholders. Behavioural changes can also be motivated by programs in which farmers feel financially motivated and an integral part of an organized collective (SCHUKAT; KUHLMANN; HEISE, 2019). After all, in order to disseminate a message efficiently, it is necessary to believe in it.

To undo the dependency on AMU in pig production requires changes in farming systems; however, without an organized intervention focused on animal welfare, the abrupt reduction or withdrawal of antibiotics can in fact promote a collapse of the production chain, as many interviewees argued. The way pigs are raised in these systems is incompatible with basic elements animal welfare and unsustainable from an environmental and ethical point of

view. Sustainable livestock systems must ensure sustainability of their consequences in the short and long term, the availability of natural resources and the ethics and morality of their practices (BROOM, 2019). Therefore, we need above all to defend animal husbandry systems committed to environmental and social license, focused on one health and one welfare (GARCÍA PINILLOS et al., 2016).

Changing AMU in pig farming in Brazil demands awareness of all layers of the production chain. It is necessary to understand the intricacies of this dependence and establish goals to improve farm practices. Agribusiness and pharmaceuticals also need to be aligned with combating AMR and promoting the rational use of veterinary antibiotics. Agroindustries should start structuring their technology parks to invest and ensure productive systems that are more harmonious between animals and the environment to strengthen pig immunity, while pharmaceutical companies must consolidate prevention strategies. Other long-term strategies such as the development of more resistant genetic lines, vaccination and eradication protocols for endemic diseases, vaccination routes facilitated for herds, among other knowledge available in the literature that the pig production chain can be appropriate (BJÖRKMAN et al., 2021; LIPSITCH; SIBER, 2016; WIERUP et al., 2021). Public authorities must mediate this transition and provide financial and legislative resources to support the changes. However, the establishment of norms without a change of behaviour and adequate training of all professionals in the production chain may produce innocuous documents without practical applicability.

This study was carried out in one of the main pig-producing regions of Brazil. Although there is variability in our sample of respondents, integrated, cooperative and independent farmers adopt similar behaviours and practices in relation to the use of veterinary drugs and pig management practices, which are in general endorsed by professionals. Further qualitative and quantitative studies are needed to provide a more complete picture of the use of veterinary antibiotics in Brazil.

7. CONCLUSIONS

These studies show that the pig production chain is anchored in a structure maintained by antibiotics. This structural relationship has social, cultural, health and economic dimensions. Restricting the use of antibiotics as a measure to reduce AMR will require a breakdown of this structure and the establishment of new, sustainable and healthy relationships, aiming above all at the welfare of animals, humans and the environment.

Raising pigs with high welfare standards is an ethical premise of agricultural professions and farmers. Reducing AMR and promoting the rational use of antibiotics in veterinary medicine is an obligation of animal and human health professionals, given the environmental and health impact that intensive livestock farming causes through the indiscriminate use of antibiotics. Our results showed that we need a change in collective thinking and the development of integrated strategies that benefit farmers, professionals and citizens in the search for a unique welfare and health approach.

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APPENDIX A

SUPPLEMENTARY MATERIAL: EXPLORING FARMERS' REASONS FOR ANTIBIOTIC USE AND MISUSE IN PIG FARMS IN BRAZIL[1]

Rita Albernaz-Gonçalves, Gabriela Olmos and Maria José Hötzel

Supplementary Table S1: Script of the interviews with the demographic questions of the study

Demographic questions
Education
Elementary school
High school
Higher education
Sex
Male
Female
Time experience
Up to 5 years
Between 6 and 10 years
Between 11 and 15 years
Between 16 and 20 years
Type of farm production
Farrow-to-finish
Breeding farms
Growing farms
Fattening farms
Herd Size
Up to 100 finished pigs
Between 101 and 500 finished pigs
Between 501 and 1000 finished pigs
More than 1000 finished pigs
Who do you sell your animals to?
Independent
Cooperative
Integrator
Other:
Labour type
Family members only
Only hired people
Family and hired persons
Does the farm have other activities besides pig farming?

[1]Supplementary material published in the jornal *Antibiotics mdpi*: https://doi.org/10.3390/antibiotics10030331

Table S2: Script of the interviews with the specific questions (biosecurity) of the study

Biosecurity issues	Frequency			
How often do you do these practices on your farm?	Always	Sometimes	Rarely	Never
Chlorine in drink water				
Rodent control				
Visitors control				
Vehicle control				
Sanitary period				
Never				
< 7 days				
7 -14 days				
> 14 days				

Table S3: Script of the interviews with the specific questions (antibiotic) of the study

Technical assistance and disease diagnosis
How do you identify which animals are sick?
How do you decide on the treatment of sick pigs?
Do you receive technical assistance on your farm?
How often do you receive technical assistance on your farm?
How do you get antibiotics and other veterinary drugs?
What is your opinion on the cost of antibiotics?
Disease prevention and control
What are the most common diseases on your farm?
Do you use medications on newborn piglets?
What medications do you use in newborn piglets?
How do you prevent genitourinary infections in sows?
How often do you supply antibiotics to the sows on your farm?
How do you prevent diseases in weaned piglets?
Could you name which antibiotics you use in the pigs' feed?
Could you name which injectable antibiotics you use in pigs?
Could you name which injectable antibiotics you use in pigs?
How do you define the dose and time of treatment with injectable antibiotics?
How do you define the dose and time of treatment with antibiotics in the feed?
In your experience, do antibiotics always work? And what do you do if they don't work?
Knowledge and attitudes about the use of antibiotics and AMR
Is there a difference between human and veterinary antibiotics?
In your opinion, are antibiotics used properly in pig farming?
In your opinion, what is bacterial resistance to antibiotics? What factors induce bacterial resistance to antibiotics?
Have you heard about prudent antibiotic use policies?
Imagine a hypothetical scenario of antibiotic restriction in Brazil, in which the use of growth-promoting antibiotics were prohibited and the preventive use of antibiotics were restricted. What would be the viability of this scenario for Brazil and what would you consider necessary in order to reduce the use of antibiotics in pigs?

[1]Supplementary material published in the jornal *Antibiotics mdpi*: https://doi.org/10.3390/antibiotics10030331

APPENDIX B

SUPPLEMENTARY MATERIAL: EXPLORING FARMERS' REASONS FOR ANTIBIOTIC USE AND MISUSE IN PIG FARMS IN BRAZIL[1]

Quotes by pig farmers: Scheme 30.a refers to the first excerpt from the interview with Farmer 30; F3b is the second excerpt quoted from the interview with Farmer 3.

30a I buy antibiotics in shops; I buy a bag [25 kg bag]. With the right dosage, I weigh it on a small scale, then mix it in the feed.

57a Yes, it is easy, you buy [antibiotics] in shops, like buying water at the bar.

50a The feed comes ready from the firm, the feed is already medicated, they put the antibiotics in it. They tell you when medicated feed will come, you have to go 28 to 30 days without carrying animals for slaughter, because you have to have a grace period, right?

3a I vaccinate [sic] with tulatromicine before weaning.

1a We control rats only when we see them. Visitors or vehicle control, we do not need that, not that many people enter here.

2a I don't need chlorine because I have an artesian well. As for control of visitors, I have a book; sometimes visitors sign, other times they don't.

3b You can't raise pigs without antibiotics.

19a In order to not need antibiotics, we will need a stronger animals, more resistant to diseases.

2b You have to do the 'shocks' every 6 months. The last time I did it was with florfenicol [amphenicols].

57b You have to do the preventions [sic], right? I use an antibiotic shocks three times a year on the entire herd, try to prevent [referring to diseases] so I don't need to spend money all the time. I do it two or three times a year and I do it in all the herd.

15a You have to see the case, sometimes it is not worth treating [the sow]. It is better to eliminate her.

17a In the pre-initial diet, for post-weaning, it is amoxicillin [aminopenicillin] in the nursery, in the initial diet it is tiamulin [pleuromutiline], then one more shock at the start of the growing phase with tiamu-lin [pleuromutiline], and at the start of the finishing phase, florfenicol [amphenicols].

19b "There is always colistin [polymyxin], it goes in all diets, since the nursery phase, because you must have it. The others I interchange according to the market, the price of the antibiotic […] Colistin you must have. I can use an amoxicillin [aminopenicillin], a chlortetracycline [tetracicline], or maybe a tiamulin [pleuromutiline].

41a Piglets are vaccinated with tylosin [macrolides] when they are born […]. After 3 days, they get iron and anticoccidials.

60a I use injectable ceftiofur [cephalosporins] at birth. If I don't, I have many piglets with arthritis during lactation.

3c Before weaning I vaccinate everyone with tulathromycin [macrolides].

18a In some farms they give the piglets tulathromycin at weaning [macrolides], it is a routine management.

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

35a	Talking about the gilts… 3 doses are usually made, sometimes of tylosin [macrolides], amoxicillin or another injectable medicine, or in the diet with doxycycline [tetracyclines] or tiamulin [pleuromutilins].
61a	Here we have very few diarroheas. Everything is controlled with the medicines they use in the sows' feed. The main thing here is cleanliness inside the nursery, right?
18b	In fact, the farm has its cycle of medication via feed, and we follow it up, by age. The cycle is continuous. There will always be some medicated animals inside the farm. Every day there is a medicated pig at some phase.
30b	Diarrhoea ends the piglet, sometimes from one day to the next it is already dead. We add just a 'little medicine' [remedinho] to control it.
51a	We do some 'little shocks'. We put medicated feed for 15 days, stop, leave a month open, add it for another 15 days…
46a	We do a lot of prevention. Both sows and piglets are like children [meaning they get sick easily]. The 'shocks' of the sows are done every 6 months, one shock during gestation and one during lactation. But during lactation it is a type of shock and during pregnancy it is another type. This is with the help of the vet, they do not usually give the same kind of shock because they say that it creates resistance.
18c	A doxycycline bag [tetracycline] costs up to 6 thousand reais [equivalent to USD 1600].
35b	You pay 250 reais [equivalent to USD 68] for 50 ml tulathromycin [quinolones].
42a	The cost is high, it is expensive, but it is worth it because you will not lose the piglet.
31a	Of course, if you have some type of disease, it is worth it. Because otherwise it ends up giving you a loss, so using the antibiotic will end up compensating.
57c	Today the integrated famer receives the information faster […] Often the independent farmer, as he has to pay, take it out of his pocket to have a veterinarian, to see someone, which has a higher cost, then often he does not pay for it.
61b	When you see that it is something you know, you go with confidence and apply the medicine. If it doesn't work we call the vet to check it out.
41b	For diarrhea, I 'vaccinate' with tylosin [macrolide].
60b	Some litters I do a single dose, others I give one the day, skip a day or two and repeat, often changing the medicine. Sometimes I do injectable oxytetracycline [tetracycline].
35c	Another day a guy who sells feed ingredients told me to use tulathromycin [macrolide] at the same time as the iron. You take 3ml of tulathromycin and take 3ml of iron from the 100 ml, you mix it in the iron flask and then you do the iron together with the antibiotics, then it is cheap.
18d	They get a antibiotic shock in the nursery, when they leave the nursery, and in growing pen. Thereafter, only if necessary, if there is an outbreak of influenza, or something that goes out of standard.
59a	The last resort is to take samples to isolate the strain from the bacteria and send it out, to find out what it is.
35d	They are similar [antibiotics for people and animals], so the Ministry of Agriculture wants us to stop using them. Usually children consume them; for example. Amoxicillin is one of the most used drugs in pigs and also one of the most used in children. That's why they want us to avoid it, so as not to cause problems for children.
1b	Resistance for me is using a medicine and in a little while it will have no effect. If I use it too long I have to change it, like amoxicillin and enrofloxacin every half year I change the medicine, if not, it no longer has an effect.
14a	Antibiotics do not work; it is resistant on the farm; the disease is resistant to a certain antibiotic.

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

58a	Low immunity in the animal; if there is a problem with it, no medication will work.
37a	I don't know for sure. I had a problem with the calves, we changed antibiotics and solved it. She gained immunity, I think that's it.
54a	Yes they worry, the less antibiotic you use, the better. Not only consumers, even us. Because if it shows up [referring to residues in the meat], I will not be able to sell anymore; today the piglets are all identified here. If there is a problem at the end of the chain, you will know that it is from my farm.
20a	I think that a lot of people no longer eat pork because of that, they're afraid of antibiotics, and then these swine flu things happen. All of this makes people suspicious of pork.
25a	When we want to fatten up a pig to eat we do it separately, only with corn and without feed, without medicines, without anything.
23a	…to catch a pig and kill it from the farm to eat it, I don't have the courage.
61c	Those who buy directly from us don't need to worry. Because they come here looking only for those pigs that we separate for us to eat, without medicines.
38a	If they cut the antibiotics it will be like this: it will decrease production, it will make the products more expensive, the poorer farmers are going to break […] I understand that today big companies want to end small ones.
4a	I think it would cut production in half. To start the farmer needs to have money…
2c	The point is that pig farming is very unstable. Most of the producers that we see are all drowning in debt… I think the laws are already well controlled, I don't see this need…
1c	Maybe I would have to adapt, do everything right from the beginning to the end. The way I work, it wouldn't work. I will always need to use a little more antibiotics…
58b	Facilities, increase the housing to have a greater sanitary period.
9a	I think it wouldn't work here [referring to Brazil] …
32a	It may be, but in Brazil I think this will go a long way…
42b	They can put the law in place, but it will be difficult to control it. … See colistin, the manufacture was prohibited, they simply went there, changed the label, instead of growth promoter they put antibiotics and released again…
16a	I think it's good, the problem is Brazil getting it. Today I don't think so. We would have to change the production system a lot, but then with the costs, today we are already working a year in the red, the production costs are already high…
33a	In the near future it will be restricted. I think it's good, no more need to use so much antibiotics […] They have to try to do something so that they don't need more antibiotics, a stronger animal, more resistant to diseases ... also encourage people, other natural alternatives, who knows?
22a	Animal welfare is also done to use fewer antibiotics. Like sows cannot stay in stalls, they have to stay more comfortable during gestation, they won't get sick and you won't need antibiotics.

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

APPENDIX C

SUPPLEMENTARY MATERIAL: MY PIGS ARE OK, WHY CHANGE? – ANIMAL WELFARE ACCOUNTS OF BRAZILIAN PIG FARMERS

R. Albernaz-Gonçalves, G. Olmos, M.J. Hötzel*

Supplementary Table S1: Script of the interviews with the demographic issues

1	Education
	Elementary school
	High school
	Higher education
2	Sex
	Male
	Female
3	Time experience
	Up to 5 years
	Between 6 and 10 years
	Between 11 and 15 years
	Between 16 and 20 years
4	Type of farm production
	Farrow-to-finish
	Breeding farms
	Growing farms
	Fattening farms
5	Herd Size
	Up to 100 finished pigs
	Between 101 and 500 finished pigs
	Between 501 and 1000 finished pigs
	More than 1000 finished pigs
6	Who do you sell your animals to?
	Independent
	Cooperative
	Integrator
	Other:
7	Labour type?
	Family members only
	Only hired people
	Family and hired persons
	Does the farm have other activities besides pig farming?
	What gestation housing do you have on your farm?

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

Supplementary Table S2: Script of the interviews with the specific issues of the study

	Specific issues
1	How often do you observe these situations on your farm? (always, sometimes, rarely, never)
	Belly nosing
	Fights in weaned piglets
	Tail biting
	Diarrhoea in weaned piglets
2	Which of these situations do you consider more serious?
	Belly nosing
	Fights in weaned piglets
	Tail biting
	Diarrhoea in weaned piglets
3	Why do pigs fight? [1]
	Temperature variation
	Nutrient-poor foods
	Mixing of pigs of different origins
	High stocking density
	Early weaning
	Boredom
	Others
4	Why do pigs do tail biting?[1]
	Temperature variation
	Nutrient-poor foods
	Mixing of pigs of different origins
	High stocking density
	Early weaning
	Boredom
	Others
5	Why do pigs do belly-nosing?[1]
	Temperature variation
	Nutrient-poor foods
	Mixing of pigs of different origins
	High stocking density
	Early weaning
	Boredom
	Others
6	What factors may be related to diarrhoea (very related, related, little related, unrelated)[1]
	Temperature variation
	Nutrient-poor foods
	Mixing of pigs of different origins
	High stocking density
	Weaning

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

	Hygiene
7	How often do you observe these situations on your farm? (always, sometimes, rarely, never)[2]
	Sows bite bars
	Sows sitting like a dog
8	Why do sows bite bars?[2]
9	Why do sows dog-sitting?
10	How much pain does a piglet feel in castration?[1] (nothing, little pain, intermediate pain, a lot of pain)
11	If castration without anaesthesia were prohibited in Brazil, how would you consider the following alternatives?[1] (unviable, barely viable, viable, I don't know how to answer)
	Castration with anaesthesia
	Immune castration
	Entire males
12	Assess the following alternatives to use at your farm (unviable, barely viable, viable)
	Offering substrate
	Decreasing animal stocking density (i.e., animals/m²)
	Weaning piglets later (i.e., at least 28 days)
	Early socialization of piglets in the nursery
	Not mixing pigs of different origins
13	Pigs are: (yes, no, I don't know how to answer)
	Smart
	Glutton
	Sympathetic
	Stubborn
	Dirty
14	Pigs have the ability to feel: (yes, no, I don't know how to answer)
	Pain
	Fear
	Happiness
	Boredom
15	Do you think pigs get stressed?
16	Do you think that stressed pigs get sick?
17	Do you think that changes in farm management can help reduce antibiotic use?
18	What does a pig with animal welfare mean to you?
19	Do you think that consumers care about animal welfare?
20	What changes would you make on your farm in a way you can say "on my farm I care about animal welfare"?

[1] These questions were randomly assigned to participants, not all of them answered on the same subject.
[2] These questions were answered only by breeding farms (n = 33).

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

APPENDIX D

SUPLEMENTARY MATERIAL: WAITING FOR MARKETS TO CHANGE ME – VIEWS OF ANTIBIOTIC USE AND ANTIBIOTIC RESISTANCE BY HIGH-STAKEHOLDERS OF THE BRAZILIAN PIG INDUSTRY

Table 14. Script Interview

1. How important are antibiotics for animal production?
2. What do you consider to be the rational use of antibiotics?
3. Does Brazilian pig farming use antibiotics rationally?
4. Definition of bacterial resistance to antibiotics
5. Relationship between AMU in animals and AMR in humans
6. Do consumers worry about AMU in animals?
7. Knowledge of prudent AMU policies
8. Definition of animal welfare
9. Is animal welfare related to AMU?
10. Assuming a hypothetical scenario in which Brazil would adopt measures of prudent AMU like international models (prohibition of antibiotics to promote growth and restriction of prophylactics), what would this scenario look like in Brazilian animal production? What is the feasibility of this scenario? What measures would be necessary to adopt these measures?

Source: Author

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

APPENDIX E

SUPLEMENTARY MATERIAL: WAITING FOR MARKETS TO CHANGE ME – VIEWS OF ANTIBIOTIC USE AND ANTIBIOTIC RESISTANCE BY HIGH-STAKEHOLDERS OF THE BRAZILIAN PIG INDUSTRY

Quotes by high stakeholders. Scheme 17.a refers to the first excerpt from the interview with Farmer 17; F3b is the second excerpt quoted from the interview with Farmer 3.

Quotes about "Importance of antibiotics in the production chain"

P17a: "In the model developed in Brazil for the production of pigs it (ATB) is essential, today it is not possible to produce properly with high productivity without the participation of antibiotics, because it is based on large-scale production, with high technology".

P1a: "Antibiotics are essential and necessary for health control and treatment of clinical conditions".

Quotes about "Production chain- Social Pillar"

P31a: "In the company we were 3 veterinarians. We met twice a year, we defined the so-called winter and summer programs. We met in April and October, and with presence of a consultant, made field visits, collected material. And within the challenges that were found in the field, mainly enteric and respiratory issues, we defined the use of medicated feed for all animals".

P30a: "The company's agricultural technician goes to the farm and leaves one or two bottles of a certain antibiotic. Diarrhoea, the farmer knows that he can only use that product, he has a list of what antibiotics are and what the deficiency is, what it is for. The pig farmer has technical guidance for this approach".

P26a: "If there is a health problem in the lot, the producer calls the technician and he goes there to take a look at the lot, if there are any more serious health problems the veterinarian follows up, and from there he decides whether to medicate or not".

P4a: "There are conflicts in this regard, because there are many veterinarians who work for the pharmaceutical industry and we know very well that the objective of any pharmaceutical industry is to sell".

Quotes about "Production chain- Sanitary Pillar"

P15a: "The preventive use of antibiotics will be more difficult to eliminate because we have many diseases on the farms. So, we will have to work on this part of risk factors and contamination. It is complicated to deal with some diseases without the preventive medication".

P32a: "In all phases, a lot of antibiotics are used. In the nursery, it is insane".

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

P1b: " ... in a situation where you need to make a prophylactic use throughout the animal's life, I think this is wrong. But at specific stages, considering the environment, due to the stress suffered by the animals, in a short period, in dosages that are not growth promoters, but appropriate to avoid a major disorder, of mortality, I understand it as acceptable".

P26b: "Many farms that do not have any isolation, have no vegetable barrier, no disinfection arch, no fence, bathing for you to enter and leave the farm, control of the entry and exit of people".

P4b: "When it comes to hygiene, disinfection, pest control in Brazil, you do not enter a farm that is not full of flies, which don't have rats. Nowadays you can't say that we do pest control or hygiene in an efficient way".

P30b: "If we take the antibiotics tomorrow and do not use any type of antibiotic in feed, for example, we would work with a much higher mortality rate, because today we are not prepared for that".

P20a: "So I think that at first we will suffer major problems with diarrhoea and respiratory diseases. This also happened in other countries and, if you look at it, maybe we will see an increase in the use of antibiotics, but not preventive, but curative".

P15b: "You would have to work hard to improve conditions, things we already know, biosecurity, with vaccination, who knows? Some protocols for the eradication of some diseases that can be eradicated within the production system. Working with production pyramids, with the health part that we know, reducing the mixture of animals".

Quotes about "Production chain- Economic Pillar"

P15c: "In terms of money, it is a great challenge to try to replace this food conversion and economic gain that the antibiotic as a growth promoter has in a country like ours".

P30c"Lately we have been receiving guidelines to stop using antibiotics for growth promotion. There are molecules that we are no longer using as colistin, which before we used a lot as a growth promoter and today, we can no longer use".

P1c: "I see that science has evolved, research has evolved considerably, in the past it was already a need because of lack of alternatives. … Today there are alternatives that give the same result as the antibiotic. . To insist on antibiotics as a growth promoter is to be outdated".

P6a: "Producing without antibiotics costs more, so you have to have money to pay for it, because you will lose in efficiency. … we cannot sell in a low-profit market like Brazil, where there are more hungry people without money to pay for this difference in cost".

P8a: "Antibiotics are not essential, without them you will produce, you will have the production of safe food, but perhaps you will not have a competitive product in the market outside Brazil".

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

P9a: “Pig farmers work with very low product margins and this means that they have to obtain financing for working capital, or to adapt the farms even to environmental legislation, and there is little room for people to make structural changes in favor of animals”.

P12a: “In my opinion as an animal scientist, about animal welfare, you have to have the maximum performance, productivity, produce respecting the premises of animal welfare. The fact is, how much does it cost for the production system? (...) it still pays off financially to disrespect the animal welfare system”.

P8b: “Part of animal welfare is that the animal is healthy. … So if you do prophylaxis, you are generating welfare…. by giving a prophylaxis you will reduce the animal's suffering…”

P14a: “Better conditions for animal welfare in farming could help reduce antibiotics, but withdrawing the antibiotic could harm animal welfare”.

P9b: “I will call it a lack of animal welfare, but I see a direct connection with these issues. We have pigs that live in a very different environment from which they evolved, with significant behavioural limitations, with agonistic behaviours, chronic stress that generates low immunity, and then we have the prophylactic use of antibiotics”.

P6b: “The first requirement for sustainable production is well-being, bioclimatology, temperature, humidity, thermal stress, this is essential. If you have thermal comfort, your animal is producing. Comfort and welfare are essential; there is no discussion, you have it, or you do not produce”.

P5a: “An animal with well-being conditions met is certainly a more productive animal, I have no doubt about it”.

P14b: “There is the other side of the industry, which is that of medicines ... a lot of people who depend on it, who earn money from it, employment with it, selling medicine ... "

P10a: “We know, both in human and animal health, there is a great influence of laboratories ... the more they are used, the more they sell, the more they earn money. And, of course, we (veterinarians) also profit…”

Quotes about “AMU/AMR”

P8c: “It has not yet been possible to prove the link of migration of possible resistance from the animal area to the human area (...) but as a precaution we are going to ban the use, that was it what the European Union did ”.

P15c: “Because although it is a global alarm, and the WHO estimates that 2050 more people will die from bacteria than from a car accident, we need to do a risk assessment to get it right (...) why? Because if you get the diagnosis wrong you can zero out the use of antimicrobials in agriculture without solving the problem in humans”.

P9c: “In the matter of public health (...) we are exposing entire populations of animals to pressure of selection of these antibiotics, and we may in the future have pathogenic bacteria

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

that cannot be controlled by medication, generating mortality and difficulties in procedures in people. So, it is a direct risk for people".

P23a: "People do not seek to know what the reality is. I think that there is a great lack of knowledge and some prejudices, but when it comes to consuming nobody cares, meat is cheap in the supermarket, nobody will look there and wonder, does this have antibiotics or not. They go there, buy and eat".

P17a: "I think that in Brazil not much yet. Brazilians are very concerned about eating, about consuming".

P18a: "There is a growing niche of people concerned with health in general, who give a lot of importance to organic products, cleaner products, this is a fast-growing market, but in Brazil it is still emerging".

P1d: "I think this is a new market, of recent years (...) as the economy stabilizes, people have more conditions and more information, people worry. The percentage of vegetarians and vegans looking for antibiotic-free products is increasing".

Quotes about "Antibiotic dependence"

P30d: "In general, today's pig farming would not be prepared for a sanction for the use of antibiotics. We still have pathogens that cause great losses in pigs, today I would not be able to have this drastic restriction in a short time".

P17b: "I think it is not only viable, but it will happen. If we don' take the measures for love, we will take the measures for pain. And this I believe will happen in Brazil, it is already happening, right, at some level. So, I think it is a way of no return for us to use antibiotics prudently".

P21a: "If suddenly the foreign market does not accept the Brazilian product if it does not submit to the rule, people pay a lot of attention to what comes from outside, this will end up being a motivator for the policies to be established".

P5b: "Brazilians are characterized by the flexibility and adaptability to market requirements and always complies with the objective of maintaining the status of one of the largest producers and exporters in the world".

Quotes about "Changes and law"

P28a: "Having regulation because the Brazilian is moved to regulation. Making access more difficult (...) There has to be a purchase control".

P1e: "So when we do a control, unfortunately, our culture starts from this principle, if there is a regulation, a stricter punishment, then it happens. Leaving just for common sense, for the good will of people is more difficult to make a significant change".

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154

P31b: “First step, to work, you need inspection”

P21a: “First thing is the technical training of professionals who are already in the field. I think that if we are not able to change this professional, through training, it will be difficult to have a good adherence”.

P9d: “I don't know if we will have the political will to implement measures to control antibiotics political system in Brazil”- Participant 9).

[1]Supplementary material publishing in the journal *Animal*: https://doi.org/10.1016/j.animal.2020.100154