UNIVERSIDADE ESTADUAL PAULISTA - UNESP
CÂMPUS DE JABOTICABAL

VALIDATING FEEDING ORDER AS A PREDICTIVE PARAMETER FOR SOCIAL HIERARCHY IN GILTS UNDER GROUP GESTATION

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Zootecnista

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TÍTULO DA DISSERTAÇÃO: VALIDATING FEEDING ORDER AS A PREDICTIVE PARAMETER FOR SOCIAL HIERARCHY IN GILTS UNDER GROUP GESTATION

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ANDRÉ ALVES DE ALBUQUERQUE, nascido em 11 de março de 1992 na cidade de Recife-PE. Formado em Zootecnia no ano de 2016 pela Universidade Federal Rural de Pernambuco, Campus Recife. Iniciou seus estudos em Etologia e Bem-estar animal em 2014, quando participou do Programa Ciência sem Fronteiras na University of Wisconsin-River Falls e teve seu primeiro contato com a área de estudos através das disciplinas de bem-estar animal e comportamento de animais de companhia. Em 2015 estagiou na Livestock Behavior Research, uma unidade do United States Department of Agriculture onde teve seu primeiro contato com atividades de pesquisas relacionadas a comportamento e bem-estar animal e desenvolveu seu trabalho de conclusão de curso. Também foi integrante do Programa de Educação Tutorial do curso de zootecnia da UFRPE por quatro anos e foi bolsista do Programa Institucional de Bolsas de Iniciação Científica do CNPq por um semestre. Em 2017 ingressou no curso de mestrado do Programa de Pós-Graduação em Zootecnia na Faculdade de Ciências Agrárias e Veterinárias – Universidade Estadual Paulista "Júlio de Mesquita Filho", na cidade de Jaboticabal-SP, como bolsista do Conselho Nacional Científico e Tecnológico (CNPq) e integrante do Grupo de Estudos e Pesquisas em Etologia e Ecologia Animal (ETCO).

“Pode dizer que meu sonho é inútil. Os loucos românticos sempre riem por último.”

Filipe Ret

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Dedico

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SUMMARY

IACUC Protocol Administration
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05-Apr-2019

PRINCIPAL INVESTIGATOR	: THOMAS D PARSONS
PROTOCOL TITLE	: Swine Teaching Herd
PROTOCOL #	: 804656
3-YEAR APPROVAL PERIOD	: 20-Dec-2018 - 20-Dec-2021

Dear DR. PARSONS:

The above referenced protocol was reviewed and approved by the Institutional Animal Care and Use Committee on **20-Dec-2018**. Protocols are valid for three years from the date of approval. However, please note that protocols with USDA-covered species and/or with funding from the Department of Defense or Department of Veterans Affairs will require annual continuing reviews. This study will be due for its next review on or before **20-Dec-2019**. Please log into the ARIES electronic protocol system (https://aries.apps.upenn.edu/laProtocol/jsp/fast2.do) on a routine basis to check the status of your protocol, and be cognizant of reminder notifications that will be sent out when new submissions are required.

Please note that the principal investigator should contact ULAR to verify animal housing availability and to coordinate activities for any special animal study needs (including special housing) or equipment requirements if this was not done during the planning phases of the protocol. IACUC protocol approval DOES NOT guarantee the availability of required resources for animal work.

Please take note of the following information:

Personnel Training: It is the responsibility of the Principal Investigator to ensure that all persons have completed all necessary training prior to participating in the research described in this protocol.
Submissions: Please note that all future submissions related to this protocol must be submitted within ARIES. No paper submissions will be accepted.
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Completion of Study: Please notify the Office of Animal Welfare once the research has been completed so the protocol can be terminated. This will prevent you from receiving unnecessary reminder notifications for renewal submissions.

If you have any questions, please contact our office as indicated above. Thank you for your cooperation with the Committee.

Sincerely,

Yale Cohen, PhD
IACUC Chair and Faculty Director of Animal Welfare

VALIDAÇÃO DA ORDEM DE ALIMENTAÇÃO COMO PARÂMETRO PREDITIVO DE HIERARQUIA SOCIAL EM MARRÃS SOB SISTEMA DE GESTAÇÃO COLETIVA

RESUMO - Agressão pós-mistura de lotes e na disputa por recursos entre marrãs e matrizes alojadas em grupos são importantes problemas associados a este sistema. Apesar da ordem de alimentação ser amplamente utilizada como parâmetro para caracterizar a hierarquia social nestes animais, esta medida ainda carece maior fundamentação científica. O objetivo deste trabalho foi o de entender as conexões sociais e a organização social de matrizes e marrãs criadas em sistema de gestação coletiva, de maneira a validar a ordem de alimentação como medida para determinação da hierarquia social. Um total de 113 matrizes e marrãs foram estudadas por quatro ciclos observacionais em um sistema de gestação coletiva equipado com alimentador automatizado. A cada 30 dias um grupo de 12 animais era substituído por novas marrãs. Um ranking de ordem de alimentação (FO) foi construído para cada ciclo observacional de acordo com o horário em que cada indivíduo se alimentou. Então, as primeiras quatro marrãs do ranking (FG1), quatro intermediárias (FG 2) e as quatro últimas (FG 3), foram selecionadas para testes diádicos, totalizando 12 marrãs selecionadas por ciclo. Nos últimos três dias de cada ciclo, comportamentos agonísticos e outros comportamentos foram observados. A frequência média de cada comportamento à entrada do comedouro foi calculada, separando-se em "Entrou" e "Não Entrou" e dividindo-se os comportamentos em três categorias: "Contato Unilateral", "Sem Contato" e "Contato Bilateral". Foi utilizado o PROC GLIMMIX do SAS para avaliar a relação entre a FO e os rankings das díades (DO) com comportamentos na entrada do comedouro para "Entrou" e "Não Entrou" independentemente. O Teste de Correlação de Spearman foi utilizado para avaliar a correlação entre FO de todos os animais da baia em cada ciclo com os comportamentos na entrada do comedouro. Foi encontrada relação estatística entre "Contato Unilateral" e FO; indivíduos do FG 1 performaram mais comportamentos agonísticos na entrada do comedouro quando comparados aos indivíduos do FG 2 e 3. Para os animais da categoria "Não Entrou" foi encontrado efeito estatístico para os que foram recipientes de "Contato Unilateral", onde animais dos FG 1 e 2 receberam mais contatos agonísticos comparados aos do FG 3. Houve efeito estatístico para animais que se envolveram em "Contato Bilateral" para os "Não Entrou", onde animais do FG 1 se envolveram em mais episódios desta categoria. Houve correlação estatística entre "Pancadas", "Empurrões" e "Contato Unilateral" com o FO em dois ciclos. Não houve correlação entre comportamentos na entrada do comedouro e o DO. Apesar dos resultados dos testes diádicos não apresentarem correlação com a ordem de alimentação, foi observado que a ordem de alimentação tem relação com o nível de agressividade dos indivíduos na entrada do comedouro, indicando que animais que entram cedo no comedouro performam mais e sofrem menos contatos agonísticos, indicando que estes animais estão posicionados em uma posição de dominância dentro do grupo. Mais estudos considerando diferentes condições de ambiência, estruturas e número de animais são necessários para entender melhor esta dinâmica.

Palavras-chave: agressão, estação eletrônica de alimentação, etologia, suínos, dominância social

VALIDATING FEEDING ORDER AS A PREDICTIVE PARAMETER FOR SOCIAL HIERARCHY IN GILTS UNDER GROUP GESTATION

ABSTRACT - Post-mixing aggression and aggression over resources between group housed sows and gilts are major issues associated with such systems. Although feeding order is a widely used parameter to characterize social hierarchy of these animals, it still lacks scientific background. Thus, the objective of this research was to understand the social connections and the dynamics involving the social organization of sows and gilts in a group housing gestation system in order to validate feeding order as a reliable and sufficient parameter for determining social hierarchy. A total of 113 sows and gilts (Yorkshire x Landrace) were studied over four observational cycles under a dynamic group housing gestation system equipped with an electronic sow feeder. Every 30 days a group of approximately 12 sows or gilts was replaced. Feeding time of each sow/gilt was collected and a feeding order ranking was built for each cycle. Then, the first four of them in the ranking (feeding group 1), four from the middle (feeding group 2), and the last four (feeding group 3), were selected for dyadic tests, totalizing 12 selected gilts per cycle. Agonistic and other behaviors at the feeder entrance in the last three days of each cycle were analyzed. The average frequency of each behavior at the entrance of the feeder was calculated, separating into successful and unsuccessful entrances and dividing behaviors into three categories: “Unilateral Contact”, “No Contact” and “Bilateral Interaction”. PROC GLIMMIX in SAS was used to evaluate relationship between feeding order and dyads rank and the behaviors at the feeder entrance, for successful and unsuccessful entrances independently. Spearman correlation test was used to evaluate correlation between feeding order of all animals in the pen in each cycle and the agonistic behaviors at the feeder entrance. Statistical relationship was found between “Unilateral Contact” and feeding order (P=0,0007); feeding group 1 individuals performed more agonistic behaviors at the feeder than individuals from feeding groups 2 and 3. For animals that failed to enter, statistical effect was found for those that were recipient of “Unilateral Contact” (P=0,0288), where feeding group 1 and 2 individuals received more agonistic contacts than feeding group 3. There was also statistical effect for animals that engaged in “Bilateral Interaction” before an unsuccessful entrance (P=0,0435), where feeding group 1 individuals having a greater number of bilateral agonistic encounters in comparison to feeding group 2. There was statistical correlation of “Knock”, “Push” and “Unilateral Contact” with feeding order on two observational cycles. No statistical correlations (P>0,05) were found between behavior at the feeder entrance and the outcomes of dyadic tests. Although the dyads outcomes did not present any correlation with feeding order rank, feeding order was related to the level of aggressiveness of the individuals at the feeder entrance and indicates that animals that eat early in the day perform more aggressive encounters and suffered less aggression, which indicates that these animals were positioned at dominant roles within the group. Further studies considering different housing conditions and number of animals are necessary to better understand this relationship.

Keywords: aggression, electronic feeding station, ethology, pigs, social dominance

LIST OF ABBREVIATIONS

AG: Aggression
BIL: Bilateral Contact
CON: Unilateral Contact
DG: Dyad Group
DR: Dyad Ranking
DS: Displace
NIN: Entrance With no Interaction
ESF: Electronic Sow Feeder
FG: Feeding Group
FO: Feeding Order
KN: Knock
LU: Lunge
MF: Mutual Fight
NCO: No Contact
NW: Nose Wrestling
PU: Push
UB: Unilateral Bite

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 – General Considerations

1. INTRODUCTION

Although group housing sows and gilts during gestation have been studied for decades, it is a relatively new requirement in the pork industry, which mainly has arisen from the need to fit minimum standards of animal welfare as the pressure from consumers keeps growing worldwide. Europe has a protagonist role in this process (Horback and Parsons, 2016) since it has always been *avant-garde* when it comes to animal welfare standards and it has been one of the first regions to have consumers concerned about the welfare of animals in the production system, with Denmark and Scotland being pioneers in the adoption of group housing gestation and influencing the rest of the continent to elaborate a comprehensive legislation over the topic (Ribas et al., 2016). This system of swine gestation has brought numerous benefits to animals, mainly related to the freedom to move around and freedom to have social interaction with conspecifics, but it also resulted in some issues that need to be addressed, such as aggression between individuals (Jensen et al., 1995; Arey and Edwards, 1998; Meunier-Salaün et al., 2002).

Thus, since aggression figures as a major collateral effect of housing sows together, inevitably, improving these systems should be guided by the species behavioral characteristics, especially related to its social aspect. Aggression between pigs is mainly related to social hierarchy definition, which consists of agonistic encounters in disputes over resources, such as feed, lying spots or any type of enrichment (Bench et al., 2013).

Particularly in group housing gestation, the fights can be very frequent and intense, especially when a new individual or a new group of animals are introduced in a pen with a previously established group (Marchant-Forde and Marchant-Forde, 2005). Overt aggression is an important measure used to identify subordinate and dominant animals within a group (Meese and Ewbank, 1973; Parent et al., 2012; Turner et al., 2017), enabling a better understanding of the social structure among animals. Thus, it is essential to study and characterize the dynamics behind sows and gilts social aggression in order to provide optimal conditions for better animal welfare, avoiding unnecessary excessive agonistic encounters, which can cause chronic stress, that, amongst other consequences, is reported to affect reproductive performance in gestating sows, bringing consequences such as embryonic losses, abortion, mummified piglets and others (Hemsworth et al., 1986).

In commercial pig production systems, the regimen of feeding for sows and gilts is restricted. This practice aims the promotion of a consistent body condition score for the animals throughout their reproductive cycles (Gonyou, 2001; Brouns and Edwards, 1994). In group gestation units that are equipped with electronic sow feeders (ESF) there is the advantage of controlling the food allocation and allows for free access to the feeder full time (Eddison and Roberts, 1995), but the amount of food is still limited and only one animal is allowed to eat at a time in an ESF, being that a trigger for a competitive atmosphere (Anil et al., 2006).

Another aggravating factor for the incidence of aggression is the entrance and removal of sows and gilts from the group pen, that is a routine procedure and is conducted either when: *i.* sows are approaching the farrowing period; *ii.* sows are coming back from the farrowing rooms; *iii.* new gilts being introduced to the group; *iv.* animals going to hospital pen; or *v.* transferred to another pen for rearranging. The introduction of new animals to the pen is a very stressful moment, as the newly introduced individuals will have to find their place in the hierarchy ranking of that previously established group (Arey and Edwards, 1998). This is translated in intense agonistic encounters until a new hierarchy order is defined, which is reported to take about three to seven days, and the subordinates use avoidance to reduce suffered aggression (Van Putten and Van de Burgwal, 1990).

One of the most commonly used parameters to determine social hierarchy in a group of sows and gilts is the feeding order, which is defined by the first time a sow or gilt had access to the feeder and had their first meal in a day (Bressers et al., 1993), although it is a very stable measure over time (Hunter et al., 1988; Bressers et al., 1993; Chapinal et al., 2008; Horback and Parsons, 2016), it has not been scientifically studied as a valid measure for this purpose. Previous studies showed that the feeding order is linked with the time that a sow or gilt has spent in the pen, also meaning that new animals are likely to eat later in the day (Bressers et al., 1993), but whether it is an evidence of social dominance or any other type of coping strategy it is still to be properly understood.

Understanding the dynamics of sows and gilts social behavior under group housing systems is essential for the advancement of behavioral researches towards the improvement of these systems of housing and feeding, and for the prospection of new systems that would promote better welfare conditions for the animals. Thus, this thesis explores the social connections and the dynamics of the agonistic encounters of sows and gilts kept under group housing gestation system, in order to validate feeding order as a reliable and sufficient parameter for determining social hierarchy.

2. LITERATURE REVIEW

2.1. Swine industry

In the following decades after the World War II, the need for more efficient food production systems and to recover the economies worldwide led to a pressure towards intensification of production processes. The improvement in the use of land, labor and enhancements on animal husbandry, associated with the development and expansion of many scientific advancements as a result of increasing international collaboration, had a major role on the industrialization of the agriculture (FAO, 1955). A process towards an animal husbandry that aimed quicker results and, consequently, submitted animals to greater challenges, such as less space allowance, monotonous environment, reduced lifespan, concentrated food and painful procedures has started and have progressed since then (Baxter, 1983; Broom and Fraser, 2015).

As a result of this process, current pork industry is one of the most important markets worldwide, since pork meat is the most consumed type of meat in the world, followed by poultry meat (USDA, 2018). Scientific advancements in nutrition, genetics and ambience played an important role in contributing for the current importance of this market. China, European Union, United States and Brazil correspond respectively to the main producers of pork meat in the world in the recent years and, consequently will have important roles in the years to come. When it comes to pork meat consumption *per capta*, Brazil switches its place with Russia in the ranking, being China (50.540 ton/year), EU (20.990 ton/year), United States (10.065 ton/year) and Russia (3.340 ton/year) the leader consumers (USDA, 2019).

In addition, world's population keeps growing in an accelerated rate and, consequently, the demand for food keeps following the same trend, demanding an estimate increase of up to 70% in world food production until 2050, in order to support this growth (FAO, 2009). Thus, intensive production systems tend to grow in importance in response to the need for increasing, not only production, but mainly the efficiency in the production systems, and as a major sector of the world's animal farming, the importance of pigs' production is expected to be even greater in the short term.

Thus, systems that aim to improve production efficiency and make better use of housing in order to enhance productivity and welfare have been studied and many of them have been implanted through the years. One of these technologies is the electronic sow feeder (ESF), which consists of a machine installed inside group pens, which enables sows/gilts to eat sequentially at any time they want, controlling their diets by recognizing an electronic ear tag attached their ear and dropping the designated amount of food for that individual in the day (Levis et al., 2013). Such system is commonly adopted at farms that house sows and gilts in group during gestation, which is a global trend towards meeting new market demands (Shields, 2017).

2.2. Group housing gestation

Pig production farms are often divided into different stages, based on the requirement of each specific phase of life, going from farrowing, nursing, growing/finishing, and gestation. The gestation stage consists of installations where the sows and gilts spend most of their lives, considering that a continuously cycling sow is a major objective (Pedersen, 2018).

There are two major types of gestation housing. The gestation stalls are the most commonly used since the start of intensification of pig production and corresponds to rooms with multiple individual cages, generally made of steel (Tonsor et al., 2009). In these stalls, sows have very limited space, and are only capable of standing and lying, not being able to turn around. It is still a widely used system, especially in United States, Asia and Brazil, mainly because of being advantageous for nutritional aspects, as well as minimizing lesions from aggression, promote easier individual handling and cheaper building costs (Harris et al., 2006; Jensen et al., 1995). However, there are some substantial disadvantages, particularly related to animal welfare, that are very harsh, such as restricting animals from exercising, exploring the environment and limiting their opportunity for social interaction (Karlen et al., 2007).

Therefore, gestation stalls are under severe scrutiny and many legislations are prohibiting this system in different European countries (United Kingdom, 2003; EU, 2001), and these new requirements are influencing companies and non-European countries to follow the same path to gradually abolish this type of gestation housing (Shields et al., 2017). In the United States, nine states (Florida, Arizona, Oregon, Colorado, California, Michigan, Rhode Island, Ohio and Maine) are examples of this process and have abolished gestation stalls (HSUS, 2013).

The other major type of gestation housing is the group gestation model. It was introduced in the 1980s (Jensen et al., 1995) and is being disseminated and promoted as an alternative to gestation stalls. A wide variation of group-housing systems is usually adopted in the industry, promoting variable conditions of space allowance, nutrition and with static or dynamic groups (Verdon et al., 2015).

Basically, the group-housing gestation systems consists of housing sows or gilts together in a pen for the most part or the entire gestational period. It can be implemented as static or dynamic groups. The first one consists of a group that will have the same animals (maximum of 20 individuals) for the entire gestational period, preferably including animals of similar parity and weight in order to avoid privilege in the access of resources and excessive agonistic encounters (Ribas et al., 2018).

The dynamic groups are recommended for larger number of animals (between 60 and 200 animals), allowing the sows or gilts to form subgroups and minimize overt aggression. This type of group housing consists of a constant periodic flow of groups of animals exiting the pen for farrowing and groups of animals entering the pen for gestation. It is important that new individuals should be introduced in small groups, to minimize vulnerability to aggression, and the disposition of hiding or separated lying areas is important to facilitate the formation of the subgroups (Ribas et al., 2016).

Additionally, floor type is one of the most important aspects which can influence the behavior and welfare of animals kept under this system (Tuyttens et al., 2008). Concrete slatted flooring is the most commonly used due to the facilitation of manure disposal, but its level of abrasiveness needs to be carefully monitored, since it is an important risk factor for the occurrence of lesions of locomotory members in sows and gilts (Kramer et al., 2015).

There is no clear consensus over a best overall system, but group pens are becoming a requirement from many companies worldwide (Shields et al., 2017), mainly because of public pressure, since this system provides freedom of movement, reduced frequency of stereotypies and the better opportunity of social interaction between individuals (McGlone et al., 2004).

Although group housing gestation figures as one important advancement regarding animal welfare for pigs in the production system, it also requires special attention, since pigs are naturally gregarious and organize themselves socially through hierarchy (Graves, 1984; Mauget, 1981), and handling and housing must be driven by this aspect of their behavior in order to achieve a satisfactory functioning system.

2.3. Swine social behavior structure

The basic social structure of groups of pigs have been studied on different settings, and wild boar and free-ranging animals have been important to understand the species natural behavior (Mauget 1981; Graves 1984). The core group consists of up to four sows, their recent litter and juvenile individuals, where the sow is dominant to the offspring and is part of a hierarchy within other sows (Mauget, 1981). The sows and offspring of the group share the same space for the daily activities and use the same nest to sleep together (Stolba and Wood-Gush, 1989). The size of the core group has been observed to vary according to the availability of resources (Mauget, 1981; Graves, 1984). This original structure is only modified during the breeding season, when a mature boar, may adhere to the core group and assume dominance over all other members (Mauget, 1981; Schnebel and Griswold, 1983).

Under natural conditions, female pigs and their young offspring spend most of their active time searching for food and eating, except when they are close to farrow, when they isolate themselves, in order to build their nest (Morrison, 2005; Graves, 1984). In those groups, overt aggression is unusual, instead they use threats to keep other individuals away, and subordinate individuals avoid competition with the dominant animals. This is mainly derived from the fact that the social hierarchy in these groups of pigs is very well established and stable, since there is little or no interaction between unfamiliar animals, and the new members of a group are essentially individuals from their own litters, which are gradually integrated (Mauget,1981).

Pigs are regrouped successively in commercial systems in order to make better use of installations and to keep uniformity of groups to maintain regularity in attending market demands. (Camerlink and Turner, 2017). And although it promotes a peak of aggression in the initial moments, as soon as the hierarchy is established, the conflicts tend to reduce, as the animals start resolving their disputes through avoidance to the detriment of performing physical aggression (Beilharz and Cox, 1967; Kongsted, 2004; Turner et al., 2006).

Considering that the unacquaintance of individuals is one of the main triggers for aggression, there is evidence that dynamic groups can be more stressful for sows than static groups. Moore et al. (1994) found that cellular immunity level was lower and plasma cortisol higher in animals kept in this system. In addition, Simmins (1993) found that aggression in dynamic groups is more abundant in comparison to static groups due to the constant flow of new animals being introduced to the pen. However, there are other studies showing no statistical differences for aggression and skin lesions between static and dynamic groups (Strawford et al., 2008; Anil et al., 2006).

2.3.1. Social Hierarchy

Social dominance is defined by van Kreveld (1970) as the priority of access to approach or have access to a resource. It is known as being bidirectional in swine, where submissive pigs may retaliate aggression from higher ranked pigs, which could be a complicating factor if it is not properly considered when housing these animals in groups. It is known that submissive sows or gilts usually have worse welfare. Being recipient of a greater number of aggressive interactions, these animals present higher number of lesions and lower body weight in comparison to higher ranked animals (O'Connell et al., 2003). Sutherland et al. (2006) findings support that social status of pigs in a group may also have an important influence on immune response, where submissive individuals presented lower white blood cells total, natural killer cytotoxicity and neutrophil phagocytosis. In addition, Hoy et al. (2009) found that animals positioned in lower positions on the social ranking presented poorer reproductive performance than dominant animals, including reduced litter size, loss of embryos and abortion.

One of the main features about pig's social behavior that is determinant for their welfare and the success at commercial setting is aggression, and this topic have been evaluated in a great set of studies, which provide plentiful information over the characteristics of this social aspect of pig's behavior that can serve as tool for improving these animals life conditions inside the production chain.

2.3.2. Aggression

One of the main features about pig's social behavior that is determinant for their welfare and success at commercial setting is aggression, and this topic have been evaluated in a great set of studies, which provide plentiful information over the characteristics of this social aspect of pig's behavior that can serve as tool for improving these animals life conditions in the production system. Scott and Fredericson (1951) defines aggression as a group of adjustments associated with behavior, including either fighting, attacks, escape, threat, defense and appeasement. It is a natural behavior displayed in a large variety of domestic species, but in swine under intensive farming it has become exacerbated due to unnatural environmental conditions and social disposition (Peden et al., 2018; Velarde, 2007). The repertoire of agonistic behaviors performed by pigs include knocks using their heads, bites, pushing by pressing other individual's body, nose nudges, threats, retreat, avoidance (Verdon and Rault, 2018; Jensen, 1980). These aggressive interactions can turn into a major issue, since, between other consequences, it may result in occurrence of lesions and more stressed individuals and consequently compromising performance (Hemsworth et al., 2013). However, pigs fight between them in order to stablish dominance and consequently award them priority of access to resources, such as water and lying spots (McGlone, 1986), and this social aspect is an unavoidable, but handleable matter when housing these animals.

In commercial production, aggression is a hindrance to the economical aspect as well as to animal welfare. This derives from the costs of treating wounds, culling of injured animals and problems in the reproductive performance of the herd (Stalder et al., 2007). Different from wild pigs in natural setting, aggressive interactions in domesticated sows are very common in production systems, being influenced by a variety of factors including body weight and space allowance (Stukenborg et al., 2011), but mainly influenced by the unfamiliarity of individuals after the mixing of unacquainted animals on a regular basis (Arey and Edwards, 1998).

Managing the size of a group adequately is a determinant point to keep low levels of aggressiveness between individuals, since pigs have been reported to recognize up to 30 individuals (O'Connell, 2009). Therefore, an adequate number of sub-divided areas inside the pen are required to allow the formation of sub-groups, which usually avoid each other (Gonyou, 2001; Moore et al., 1996). Since the unacquaintance of individuals plays a major role in triggering aggressive behaviors, larger groups tend to present higher frequency of agonistic encounters (Drickamer et al, 1999; Ewbank and Bryant, 1972). That may derive from the fact that pigs are animals that naturally live in small groups of familiar individuals for their whole lives, rarely interacting with individuals from a different group (Graves, 1983; Mauget, 1981).

Although aggression levels represent a major problem after mixing sows and gilts, the rates of agonistic encounters tend to be significantly reduced after three days (Marchant-Forde et al., 2009), and an avoidance order results in dominant animals needing to perform agonistic behaviors less frequently, which leads to a general reduction of aggression within the group (Broom and Fraser, 2015). Once the social hierarchy is stablished, episodes of aggression are more common during competition or defense of a limited resource to the detriment of disputes over social dominance (Verdon and Rault; 2018).

In commercial herds, levels of aggressiveness have been reported as being a main indicator of social hierarchy rank (Drickamer et al., 1999; McGlone, 1986), but sows also may present different coping styles according to the environment and conspecifics in order to reduce levels of suffered aggression and access to resources, which may have a strong influence on the social rank position (Ison et al., 2010; Forkman et al., 1995; Mendl et al. 1992). Thus, it is of great interest to characterize the dynamics of groups of gilts and sows, aiming the promotion of systems which has lower possibilities of fomenting social stress.

2.4. Methodologies to evaluate social behavior in pigs

Several social behavior tests are described in the literature and are important tools in understanding and helping the decision-making process involving group housing gestation systems. These tests and measures are used to understand different aspects of social behavior and for an efficient and reliable combined use the aspects being measured should be well identified. Some of the most commonly used tests and measures involving social behavior of pigs (especially of sows and gilts) found in the literature are:

i. Continued behavioral observation of sows or gilts in a pen is widely used to identify animals involved in agonistic encounters, patterns of pen exploration and access to resources, enabling the characterization of dominant and submissive animals and the creation of a social hierarchy rank (Greenwood et al., 2017; Turner et al., 2017; Meese and Ewbank, 1973);

ii. Dyadic tests aims to identify the type of direct social relationship between each pair of animals housed in the same group, and it consists of conducting two animals to a neutral testing pen, and offering a small trough of food (where only one individual is able to eat at a time). It is expected that dominant individual will have priority access to the food and protect it from the submissive individual. The test is ended when an animal is successful in having exclusive access to the food, and then a retest is done in the sequence, in which the food trough is offered to the initial “loser” and the result is confirmed if this individual gets displaced, or is marked as a tie if this individual is successful in this second test (Parent et al., 2012; Brouns and Edwards, 1994);

iii. Another social behavioral test is the resident-intruder test, which consists of maintaining an individual resident pig in a separate part of the home pen and then introducing a smaller and unacquainted individual in this separated area. The tendency is that the resident pig will attack the smaller individual and then the latency between introduction of the new animal and the first attack is registered. This test is mainly used to objectively assess the consistence of aggressiveness of an individual over time (Camerlink et al., 2016; D'Eath and Pickup, 2002; Erhard and Mendl, 1997);

iv. Dominance testing, described by Ison et al. (2010) utilized the frequency and category of agonistic encounters (short attack, long attack, avoidance and retreats) to identify dominant and submissive individuals by spreading food on the floor and making direct behavioral observations. This test was done with gilts before mixing and this observation generated a ranking where the highest ranked animal was the least defeated individual and the lowest ranking animal had the most defeats;

v. Feeding order, which is a practical and widely adopted method of studying gilts and sows' social hierarchy, consists in the order in which each individual in the pen has access to the feeder after the start of each daily feed cycle, which generally consists of 24 hours. This test is especially applied in pens equipped with electronic sow feeders, identifying each animal and its respective time of the first entrance to the feeder, considering that dominant individuals tend to eat earlier in the feeding cycle (Chapinal et al., 2008; Bressers et al., 1993 and Hunter et al., 1988).

Additionally, social behavior of pigs can be also evaluated through indirect measures involving reproductive performance (Hemsworth et al. 2013; Hoy et al., 2009), immunity response (Sutherland et al. 2006; Moore et al., 1994), nutritional performance (O'Connel et al., 2003), injuries (Morgan et al., 2018; Stevens et al., 2015), and offspring behavioral development (Ison et al., 2010). These measures can give an overview of the quality of the social environment in which the sow or gilt is inserted and enables to predict issues with housing and handling protocols.

These behavioral tests and measures may bring numerous information to study and characterize social hierarchy in group housed sows and gilts. Although, feeding order still lacks scientific validation, and the number of studies using this measure to evaluate social behavior of swine is still limited. Thus, the objective with this thesis is to understand the social connections and the dynamics of the agonistic encounters of sows and gilts kept under group housing gestation system in order to validate feeding order as a reliable and sufficient measure to characterize social hierarchy of gilts under group housing gestation system.

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CHAPTER 2 – Does feed order predict social hierarchy of group-housed gilts?

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ABSTRACT – The objective of this study was to understand the dynamics of the social behavior of sows and gilts in a group housing gestation system, in order to validate feeding order as a reliable and sufficient parameter for determining social hierarchy. A total of 113 sows and gilts were studied over four observational cycles under a gestation group housing system equipped with an electronic sow feeder. A feeding order ranking was built for each cycle. Then, the first four gilts of the ranking (feeding group 1), four from the middle (feeding group 2), and the last four (feeding group 3) of each cycle, were selected for dyadic tests. Agonistic behaviors at the feeder entrance were also analyzed in each cycle. The average frequency of each behavior at the entrance of the feeder (Displace, Push, Nose Wrestling, Knock, Unilateral Bite, Aggression, Mutual Fight and Lunge) was registered and posteriorly divided into three categories: unilateral contact, no contact and bilateral agonistic encounters. PROC GLIMMIX in SAS was used to evaluate the relationship between feeding order and dyads rank and the behaviors at the feeder entrance, for successful and unsuccessful entrances independently. Spearman correlation test was used to evaluate the correlation between feeding order of all animals in each cycle and the agonistic behaviors at the feeder entrance. Higher ranked gilts presented more aggressive interactions at the feeder entrance. Statistical relationship was found between entrance with any agonistic encounter and feed order (P=0.0007); animals that ate earlier performed more agonistic behaviors. For animals that failed to enter, statistical effect was found for those that were recipient of agonistic encounters (P=0.0288), where animals that ate earlier were recipient of greater number of agonistic behaviors. There was also statistical effect for animals that engaged in bilateral agonistic encounters before an unsuccessful entrance (P=0.0435), where feed group 1 individuals having a greater number of bilateral agonistic encounters in comparison to feed group 2. There was a statistical correlation of “Knock”, “Push” and ”Unilateral Contact” with feeding order on two observational cycles. Feeding order was found to be related to the level of aggressiveness of the individuals at the feeder entrance and indicates that animals that eat early in the day perform more aggressive encounters and suffered less aggression, which indicates that these animals were positioned at dominant roles within the group. Further studies considering different housing conditions and number of animals are necessary to better understand this relationship.

Keywords: aggression, electronic feeding station, ethology, pigs, social dominance

1. INTRODUCTON

Housing of gilts and sows in gestation group housing systems has been studied as an alternative to gestation stalls since the 1980's (Den Hartog et al., 1993). However, just recently it has turned into a major requirement for some countries and companies worldwide (Shields, 2017; EU, 2013). Although it represents many advantages related to animal welfare, such as opportunity of social interaction and freedom of movement, it has also brought some issues which include increased incidence of claw lesions and aggression between individuals, which may contribute to the occurrence of lesions and decreased reproductive performance (Morgan et al., 2018; Hemsworth et al., 2013).

The study of social behavior of pigs is detailed in free-ranging and wild groups (Stolba and Wood-Gush,1989; Mauget, 1981). This background is essential to understand the principles of the social organization of these animals in commercial settings as well, since the possibility of social interaction brought by the gestation group system allows the formation of a hierarchy system (Verdon et al., 2015), which is similar to their wild conspecifics.

Under industrial pig production, individuals are constantly reallocated, and the social hierarchy reformulation after mixing unacquainted individuals results in intense aggressive behaviors between individuals, representing a major challenge in group housing sows and gilts during gestation (Marchant-Forde and Marchant-Forde, 2005). The intense episodes of aggression have a peak in the first 3 days post-mixing (Marchant-Forde et al., 2009), however high levels of aggressiveness can last for up to 10 days (Van Putten and van de Burgwal, 1990), when the new hierarchy starts stabilizing, and animals gradually recognize their position, displaying threats and avoidance instead of physical altercations (Arey and Edwards, 1998).

Several strategies to minimize aggression between gilts and sows are described in the literature. One of the main practices adopted is to introduce new individuals to a pen in groups of at least three sows or gilts and provide “hiding areas” which will enable new individuals to evade from aggression and also allows for the formation of subgroups (Ribas et al, 2016). However, these strategies should rely on the knowledge of the social behavior of these animals in the pen and the development and adoption of new strategies to provide a socially healthy environment, reducing the possibilities of excessive episodes of aggressions, which may particularly affect submissive individuals and worsen their welfare.

Electronic sow feeders (ESF) allow for a deeper attention on each individual in a pen and facilitate new strategies to study how these animals cope with the group housing gestation system. One of the most commonly used parameters to study or evaluate sows and gilts behavior in this system is the feed order, which focuses on the daily order in which sows and gilts use the feeder. It figures as an important, practical and consequently widely used measure, which is defined as the temporal order in which the individuals make their first visit to the feeder in a feeding cycle (Bressers et al., 1993).

It is reported that feed order might be directly related to dominance, with dominant individuals having priority of access to the feeder and consequently eating earlier in the feeding cycle (Bressers et al., 1993). This measure may be a practical alternative to characterize social hierarchy in a group of gilts and sows and is also an asset for studies which focus on feeding behavior. It has been used not only in studies involving pigs (Kruse et al., 2011; Chapinal et al., 2008; Lembeck et al., 1996; Bressers et al., 1993; Edwards et al., 1988; Hunter et al., 1988), but also with other species such as feral cats (Bonanni et al., 2007) and cows (Livshin et al., 1995).

The easy applicability of feeding order makes it a great asset either for commercial herds or for research purposes, however, the dynamics that influence the order in which sows and gilts visit the feeder still needs further scientific validation to clarify which aspects of social behavior feeding order is able to depict. There are limited in-depth studies evaluating this parameter applied to sows and gilts under group housing gestation, and to the best of our knowledge this is the first study aiming the validation of feed order as a social hierarchy parameter for sows and gilts under group housing gestation.

2. ANIMALS, MATERIALS AND METHODS

This research study was carried out in accordance with the United States of America legislation and was approved by the University of Pennsylvania's Institutional Animal Care and Use Committee (Protocol #804656).

2.1. Animals and Housing

The study was carried out at the Swine Teaching and Research Unit at New Bolton Center – University of Pennsylvania, located in Kennett Square, Pennsylvania, United States of America, between November 2018 and February 2019. The unit consists of gestation, farrowing and nursing stages. This study was conducted in one of the pens of group gestation housing (163.55m^2), which housed an approximate mean of 80 sows (2.4m^2 per animal) with controlled room temperature and equipped with an electronic sow feeder (ESF) (Schauer Agrotronic Compident 7®), three bowl drinkers and eight resting areas with concrete solid flooring and separated by white acrylic walls, while the rest of the pen had concrete slatted floor. The ESF was accessible to the animals 23 hours per day, staying closed from 11pm until 12am, when it reopened, and the diet of the new day was made available. The animals were allowed to make unlimited visits to the feeder and consume their designated daily diet in as many visits as they wanted/needed. The gestation group consisted of a dynamic system, in which about 12 new gilts entered the pen, on each cycle with intervals of about 30 days and consequently, about the same number of animals was removed for farrowing rooms or rearranged to another pen. These 12 new individuals were trained for two weeks to use the ESF properly. This training consisted in conducting each animal to the ESF daily, assuring that each individual has learned to use the equipment spontaneously by the end of the training period. Then, the 12 new gilts were transferred to the experimental pen. A total of 113 Line 241 gilts and first parity sows (DNA Genetics, Columbus, NE) were used throughout four observational cycles of this research. The animals were identified with numbers painted on their back with ammonia-free black hair dye.

2.2. Feeding Order

The ESF software data was used to access the feeding order of the gilts and sows of the pen. The feeding order was generated considering an ascending order of time of first visit to the ESF, starting at midnight for each observation day. Then, a total of 12 gilts were ranked on each cycle (1: four from the top, 2: four from the middle and 3: four from the bottom), considering mean ranking from the last five days of each cycle. Only zero parity animals were included in this selection and pregnancy was also balanced between the selected gilts, selecting for six pregnant individuals and six non-pregnant individuals.

2.3. Dyadic Tests

The 12 gilts selected using the feeding order ranking criteria were then submitted to dyad tests at the end of each cycle. The test was adapted from Brouns and Edwards (1994) and Parent et al. (2012): a neutral pen (3,2m x 5,7m) and a small bowl feeder (25 cm diameter) were used and prior the first test of each cycle, each gilt individually had two minutes of recognition of the testing pen. To standardize food motivation, the diets from the 12 selected gilts were reduced to 25%, and the remaining 75% was fed at the end of each recognition or testing day. During the recognition, a gilt was introduced to the testing pen and received a small portion of food in the bowl feeder.

The test started with two gilts being escorted to the testing pen and then, an observer placed the small bowl containing about 100 grams of regular diet at an equal distance from both gilts, attracting both gilts attention. During the test, an observer registered the agonistic interactions between the animals and the test was finished when one of the sows had eaten all the food from the trough or has had exclusive access to the through for more than five seconds. Then, a retest was done by offering another 100 g of food to the loser in the trough, making sure that the first winner was able to see it. If this gilt was displaced by the first winner, the result was confirmed and the winner was considered dominant over the loser, otherwise it was marked as a tie. After that, the gilts were escorted back to their home pen and the next dyad was conducted. Each of the 12 gilts was tested with each of the other gilts, assuring that each gilt could only be tested 3 times a day and no gilt could be tested twice in a row. All the tests were also filmed (with camera Exmor R SteadyShot by Sony Corp.©), for further analysis in case of inconclusive results.

A ranking considering number of wins, ties and losses was created using the model of matrix of relationships adapted from Appleby (1994), where a winner individual was scored 1 point, the loser scored 0 and in case of ties the score was 0.5 for each individual. A ranking was created for each observation cycle, from 1 to 12 in a descending order of points scored, where 1 was the top position and 12 the bottom. Further, this ranking was also divided into 3 parts, denominated dyads groups (DG), where DG 1 contained the first top four individuals (those that won more dyads), DG 2 contained the 4 intermediary individuals and DG 3 contained the last 4 individuals (individuals that had lost the higher number of encounters).

2.4. Behavior at Feeder Entrance

A video camera (IPX DDK-1700D Infrared IP Dome Camera, Farmingdale, New Jersey) was installed at the roof of the pen, filming the neighboring area of the ESF entrance gate in order to record the interactions between all sows or gilts present in the pen, during feeding time. To evaluate the behavior at the feeder entrance the following protocol was adopted:

i. The last three days (72 hours) of each observational cycle were filmed for further analysis;
ii. The video scoring was conducted considering an ethogram adapted from Camerlink et al., (2016) and Greenwood et al., (2017) (Table 1);
iii. The video recordings were watched continuously through the 72 hours, and when an entrance of an individual the ESF was detected, the video was paused, the animal that entered was identified and registered by its number, and the video was rewound to a minute before the entrance episode.
iv. This 1-minute interval before an entrance was observed and then all the agonistic behaviors displayed by any sow or gilt in the area captured by the camera in this time interval were registered, according the ethogram described in Table 1.

Table 1. Ethogram of the behaviors recorded at the feeder entrance and their respective codes and description

Behavior	Code	Description
Displace	DS	Use any part of the body to put pressure against another individual resulting in its dislocation towards opposite direction
Push	PU	Use any part of the body to put pressure against another individual not resulting in dislocation of the other individual
Nose Wrestling	NW	Both firmly press the side of their nose against the side of the nose of the Other
Knock	KN	Use nose or head in a quick movement to hit another sow
Unilateral Bite	UB	To open the mouth and firmly closing it against any part of the body of another individual
Aggression	AG	Episode of 3 or more sequential pushing, knocking or biting.
Mutual fight	MF	Aggressive act, e.g. biting and pushing, which is retaliated with an Aggressive act within 5 s. Continues until one retreat or until other behavior is performed for at least 3 s
Lunge	LU	To impose its body in the direction of an opponent in a similar action of attack, but retracting before any contact with opponent.

2.5. Statistical Analysis

First, the average frequency of each behavior at the entrance of the feeder was calculated for the three observational days for each animal belonging to the feeding order rank. This average was separated by animals that were successful or not successful in entrance. Then, those behaviors were divided into three categories: i. behaviors that involved any unilateral contact (CON) which included: DS, PU, KN, UB and AG; ii. Behaviors that involved bilateral contact (BIL), which included: NW and MF; iii. Behaviors that involved threat but did not involve any physical contact (NCO), which included: LU.

Linear mixed models, using PROC GLIMMIX in SAS, was used to evaluate if there was a relationship between the feeding order and the dyads rank (independently) and the behaviors at the entrance of the feeder (CON, NCO, BIL). All models included the feed order and dyads ranks, independently (1, 2 or 3) as fixed effects and cycle was included in the model as random effect. The model was performed independently for the animals that were successful or not successful in entrance of the feeder. For those that succeeded in the entrance, the behavior entrance without any interaction (ENI) was also evaluated.

Spearman correlation test was used to evaluate if there is a correlation between all animals feeding order, considering not only the selected gilts for the rank, but all the animals on each cycle, with the behaviors at the feeder entrance (DS, PU, NW, KN, UB, AG, MF, LU) and also with CON, NCO and BIL. This correlation was done considering either animals that entered successfully and animals that did not succeed.

3. RESULTS

3.1. Dyad Ranking vs. Feeding Order

Each cycle produced a feeding order, from 1 to 12 in descending order, feeding groups, from 1 to 3, a dyad ranking, from 1 to 12 and a DG, from 1 to 3. Comparing the feeding group of each animal with the dyad groups in the four observational cycles, no direct relationship was observed, since in 54.00% of the occasions the FG did not match the dyad group. Table 2 depicts feeding order, feeding group, dyad ranking and dyad group for each observational cycle.

Table 2. Feeding Order (FO) and Feeding Group (FG), Dyad Ranking (DR) and Dyad group (DG) of each gilt in each observation cycle (1, 2, 3 and 4).

Cycle 1	Gilt ID	**2**	**7**	**10**	**11**	**19**	**20**	**21**	**34**	**36**	**48**	**51**	**57**	
	FO(FG)	12(3)	9(3)	10(3)	11(3)	7(2)	5(2)	8(2)	4(1)	6(2)	1(1)	2(1)	3(1)	
	DR(DG)	10(3)	4(1)	6(2)	1(1)	5(2)	3(1)	7(2)	2(1)	12(3)	9(3)	11(3)	8(2)	
Cycle 2	Gilt ID	**3**	**7**	**11**	**29**	**43**	**51**	**53**	**54**	**63**	**66**	**70**		
	FO(FG)	7(2)	8(2)	11(3)	6(2)	1(1)	2(1)	5(2)	4(1)	3(1)	10(3)	9(3)		
	DR(DG)	7(2)	6(2)	2(1)	1(1)	3(1)	10(3)	4(1)	9(3)	8(2)	5(2)	11(3)		
Cycle 3	Gilt ID	**14**	**26**	**34**	**43**	**44**	**54**	**62**	**65**	**66**	**70**	**74**	**101**	**108**
	FO(FG)	6(2)	10(3)	2(1)	1(1)	4(1)	8(2)	7(2)	5(2)	9(3)	11(3)	3(1)	12(3)	13(3)
	DR(DG)	13(3)	11(3)	2(1)	1(1)	6(2)	12(3)	3(1)	8(2)	4(1)	7(2)	5(2)	9(3)	10(3)
Cycle 4	Gilt ID	**44**	**63**	**66**	**68**	**69**	**70**	**74**	**98**	**104**	**115**	**116**	**119**	
	FO(FG)	6(2)	8(2)	4(1)	7(2)	10(3)	11(3)	1(1)	5(2)	2(1)	12(3)	3(1)	9(3)	
	DR(DG)	8(2)	3(1)	1(1)	5(2)	4(1)	11(3)	6(2)	12(3)	7(2)	9(3)	2(1)	10(3)	

3.2. Behavior at feeder entrance

Considering all observational cycles, for individuals that successfully entered, a total of 66.64% episodes of entrance to the feeder did not involve any agonistic interaction. Between the entrances that involved agonistic behaviors, episodes of Aggression (AG) represented 3.96% of the episodes of agonistic interactions before an entrance episode. Knock (KN), Displace (DS), Push (PU) and Unilateral Bite (UB) corresponded, respectively, to 28.62%, 33.14%, 9.48% and 6.44% of the total agonistic interactions before an entrance episode. Regarding the bilateral behaviors, Nose Wrestling (NW) was displayed in 4.21% and Mutual Fight (MF) had the lowest occurrence between the agonistic behaviors, with 0.31% of the total episodes. No-contact agonistic behaviors which corresponded to Lunge (LU), represented 13.81% of all episodes.

For behaviors presented in unsuccessful entrances, AG represented 5.95% of the agonistic behaviors; DS was performed in 8.93%; KN had the higher percentage with 42.14% of the agonistic behaviors; PU was performed in 10.3% of the agonistic encounters; UB represented 11.27%. Regarding no contact agonistic behavior, LU corresponded to 17.04% to all agonistic encounters. The bilateral behaviors, NW and MF, represented 3.93% and 0.41% respectively. Figure 3, portrays the frequencies of occurrence of each behavior over a period of one minute before feeder entrance, separated by animals that were successful or not successful in entrance, considering all the agonistic behaviors.

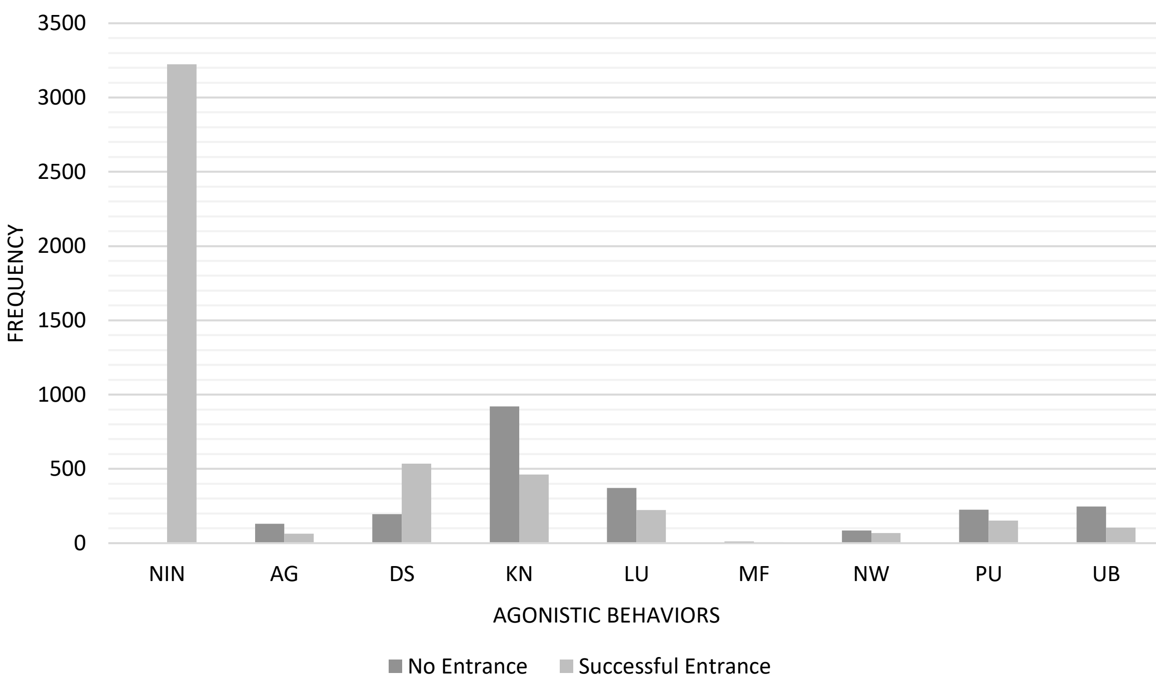

Figure 1. Comparison of total number of episodes (considering all observational cycles) that each agonistic behavior (NIN= Entrance with no interaction, AG= Aggression, DS= Displace, KN= Knock , LU= Lunge, MF= Mutual fight , NW= Nose Wrestling ,PU= Push, UB= Unilateral Bite) was executed, considering the 1-minute interval before a successful or not successful in entrance.

3.3. Feeding Order vs. Behavior at feeder entrance

3.3.1 Correlation between feeding order rank and behaviors at the entrance of the feeder

There was a statistical relationship between CON (before successful entrance) in the entrance of the feeder and feeding order ($F_{2, 29}$= 9.37; P=0.0007). Animals in the first rank group of feeding order (FG 1) performed more CON (0.79 ± 0.24) than animals in the second (-0.04 ± 0.24) and third (-0.19 ± 0.26) feeding order (estimated means ± SE), which did not differ between them for agonistic behaviors. For the other behaviors (ENI, NCO e BIL) there was no statistical interaction with feeding order (P > 0.05).

For animals that did not enter after being engaged in an agonistic interaction, there was statistical relationship between CON and feeding order ($F_{2,39}$= 3.89; P=0.0288). Animals belonging to feeding group 1 (FG 1) received more agonistic contacts (1.07 ± 0.17) than those from feeding group 3 (FG 3) (0.38 ± 0.18), but did not differ from feeding group 2 individuals (FG 2) (0.65 ± 0.17) (estimated means ± SE). In addition, there was statistical relationship between BIL and feeding order ($F_{2,5}$=6.26; 0.0435). Feeding order 1 individuals had a greater number of bilateral encounters before an unsuccessful entrance (-0.27 ± 0.19) and differed statistically from feeding order 2 individuals (-1.10 ± 0.16) but did not differ from feeding order 3 individuals (-0.50 ± 0.18). Table 3 depicts real means for each behavior category for each feeding rank.

Table 3. Means of No Interaction (NIN), Contact (CON), No Contact (NCO) and Bilateral Interaction (BIL) when an individual had a successful entrance (Entered) or failed to enter the feeder (No Entrance) by each feeding group (FG).

	Entered				No Entrance		
FG	NIN	CON	NCO	BIL	CON	NCO	BIL
1	3.687^{a}	2.104^{a}	0.291^{a}	0.145^{a}	3.375^{a}	0.562^{a}	0.145^{a}
2	4.095^{a}	1.071^{b}	0.071^{a}	0.047^{a}	2.416^{a}	0.588^{a}	0.083^{b}
3	4.666^{a}	0.645^{b}	0.062^{a}	0.062^{a}	1.458^{b}	0.500^{a}	0.125^{ab}

$^{a-c}$ Means followed by the same lower-case letters in the same column are not statistically different (P > 0.05), by Tukey test.

3.3.2 Correlation between feeding order and entrance behaviors

No significative correlation was found between feeding order and any of the agonistic behaviors on cycle 1 and cycle 3. On cycle 2, there were significative and negative correlations between feeding order and “Knock” (KN) (r= -0.31, P= 0.01), “Push” (PU) (r= -0.3487, P= 0.005) and “Unilateral contact" (CON) (r= -0.3942, P=0.001). There were also significative and negative correlations between feeding order and “Knock” (KN) (r= -0.2989, P= 0.0252), push (PU) (r= -0.3168, P=0.0174) and “Unilateral contact” (CON) (r= -0.3400, P= 0.0103) on cycle 4. This means that as higher is the feeding order of the gilts (those ones that enter the feeder later in the day), lower the number of agonistic behaviors performed by them.

3.4. Behavior at Feeder Entrance vs. Dyadic Test

No statistical correlation (P> 0.05) was found between dyads groups and entrance with no interaction, entrance with any interaction, entrance after threat, entrance after bilateral interaction, unsuccessful entrance after contact, unsuccessful entrance after being threatened, and unsuccessful entrance after bilateral interaction. The means of number of interactions (NIN, CON and BIL) are showed in Table 4 for each dyad rank.

Table 4. Means of No Interaction (NIN), Contact (CON), No contact (NCO) and Bilateral interaction (BIL) when an individual had a successful entrance (Entered) or failed to enter the feeder (No Entrance) by each dyad group (DG).

	Entered				No Entrance		
DG	NIN	CON	NCO	BIL	CON	NCO	BIL
1	3.755	1.400	0.244	0.066	2.687	0.520	0.104
2	4.377	1.888	0.111	0.133	2.687	0.687	0.145
3	4.312	0.604	0.083	0.062	1.875	0.437	0.104

4. DISCUSSION

4.1. Dyadic test vs. feeding order

Although feeding order and dyadic tests have been used to evaluate social hierarchy in the literature, in this study we were not able to detect any relationship between these variables. Possibly, despite the habituation process adopted, the dyads may have represented an unusual situation for the individuals, altering their response to the presence of another individual. Another possibility is that the occurrence of social subgroups in the pen could facilitate the access to the feeder (Ribas et al., 2016; Moore et al. 1994), resulting in a a totally different dynamic compared to the dyad testing experimental pen, i.e. pigs may have interacted with each other for the first time in the experimental pen. This is an important finding, since there are no studies comparing such measures of social behavior of pigs. The use of dyadic tests by Parent et al. (2012) and Brouns and Edwards (1994) aimed the building of a social rank, and considered the rank resulted from dyads as a social hierarchy ranking. However, our study has found divergent patterns between dyadic test outcomes and the feeding order rank, which may be an indicator that each measure is assessing a different aspect of the social behavior of sows and gilts, especially in a large and dynamic group, and further investigation on this subject is needed.

4.2. Behavior at the feeder entrance

Considering the frequency of the agonistic behaviors at the feeder entrance, the entrances that did not involve any agonistic interaction (NIN) appeared as the largest percentage. This fact was expected and can be explained by the time of four weeks that the group of sows and gilts have had together in the pen before the observational period, allowing a proper hierarchy definition, which is reported to take about two to ten days, according to Moore et al. (1993) and Arey (1999). In addition, we hypothesize that animals that were involved more frequently in agonistic encounters (as recipient or as initiator) may have had more distractive moments at the feeder entrance, spending more time engaged in disputes for space, which may have represented an advantage for the animals that did not engage in agonistic interactions. An alternative hypothesis is that individuals that used to eat later may have encountered a less crowdy environment at the surroundings of the feeder, since our study found a larger number of individuals are disputing the entrance of the feeder in the first hours of the feeding cycle, which agrees with Hunter et al. (1988).

4.3. Behavior at the feeder entrance vs. success at feeder entrance

Animals that succeeded to enter the feeder were involved in a greater number of "Displace" DS. Making a parallel with Graves (1984) findings, who have observed dominant free-ranging sows displacing subordinates from food sources, we can consider that animals which succeeded at the feeder entrance were dominant over the others that were also trying their way into the feeder. This data also corroborates with Drickamer et al. (1999) and McGlone (1986), who reported that social dominance has a direct relationship between aggression rates. The predominance of DS, specifically, could have been observed because this particular behavior, in this study, was observed to be predominantly performed closer to the feeder gate, especially during the final moments before the gate opening. Thus, this behavior has been displayed by animals that may have already been at an advantage point, consequently guaranteeing a higher chance for the individual to be successful in the entrance attempt, removing direct opponents during the final moments before the gate opening. The fact that these animals were able to be closer to the feeder gate also points towards the probability that these animals were socially dominant or had a better strategy in making their way to the feeder entrance.

4.4. Feeding order vs. behavior at the feeder entrance

The statistical relationship found between feeding order rank and behaviors at the entrance of the feeder that were successful at the feeder entrance implies that animals positioned at top positions of feeding order performed more agonistic behaviors that involves unilateral contact (CON). This result agrees with O'Connell et al. (2003), who stated that individuals that performs a greater number of aggressive initiatives, occupies the first positions in the social hierarchy. Our result also agrees with Munoz et al. (2015) who found that dominant and sub-dominant sows (which can be represented by feeding groups 1 and 2 in this study) displayed a greater number of agonistic behaviors, than subordinate individuals (represented by feeding group 3 in this study), while subordinates received a higher number of agonistic behaviors than the other two categories. It also implies that the animals that initiate interactions that are more aggressive tend to displace less aggressive individuals and enter earlier in the feeder.

Additionally, animals that did not enter the feeder were statistically different between feeding groups regarding receiving CON before the entrance. Individuals from feeding groups 1 and 2 had means statistically higher in comparison to feeding group 3, indicating that individuals from those two feeding groups were recipient of a greater number of agonistic interactions. Since the behavioral observations took place after the animals have been together for approximately four weeks, this probably means that the social hierarchy was already well established (see Moore et al., 1993; Arey, 1999; Marchant-Forde, 2009). These authors also show that as the hierarchy is established, the number of aggressive encounters tend to diminish, as submissive individuals increase avoidance to dominant pigs and, on the other hand, dominant individuals need to perform less agonistic contacts in order to defend resources, using more threats, instead. This can explain the reduced frequency of received agonistic behaviors by the gilts belonging to the last group of the feeding rank (3), with these animals getting involved in less disputes, probably by avoiding the dominant animals by eating later in the feeding cycle.

The frequency of “Knock” KN, “Push” PU and “Unilateral Contact” CON presented a negative correlation with feeding order in cycles 2 and 4, meaning that as an individual ate later in the day, the frequency of these agonistic behaviors was lower. This pattern indicates that with higher ranking in the feeder order, sows and gilts perform the most submissive behavior. It also sums up with the fact that our results also indicated that these animals were recipient of agonistic behaviors in a lower frequency than individuals belonging from feeding group 1 and 2, which may indicate that individuals from feeding group 3 could be eating later to avoid aggressive encounters with the top ranked animals. Similar patterns were previously discussed by Broom and Fraser (2015) and Gonyou, 2001, who had reported the existence of an avoidance order in groups where the social hierarchy was previously stablished. This concept considers that the dynamics of social interactions between pigs are not only regulated by aggressive behaviors, but also by avoidance behaviors, that are utilized to escape from possible aggressive interactions and are displayed in response to the presence of specific individuals positioned in a higher hierarchy ranking (Jensen, 1982).

A very limited frequency of bilateral agonistic interactions (BIL) was observed during this study, and this may be justified by the time that the individuals have had together, which allowed the definition of the social hierarchy, corroborating with Karlen et al. (2007), who had observed that the aggressive encounters between individuals inside a well stablished social group are less likely to be retaliated.

4.5. Dyadic test vs. behavior at the feeder entrance

Our study was not able to find statistical relationship between dyad outcomes and the average of behaviors at the feeder entrance, neither successful nor non-successful entrance. Although the dyadic test we used was previously used to identify social dominance between individuals (Parent et al., 2012; Brouns and Edwards, 1973), it seems that the dynamics of social hierarchy during this type of test represent a different situation for gilts housed in a large dynamic group of gestation.

It has been reported that pigs have the capacity to recognize up to 30 individuals (O’Connell, 2009), therefore, the formation of sub-groups inside a higher sized group, as the condition the gilts were kept in the present study, will allow them to usually avoid other individuals that not belong to their subgroups (Gonyou, 2001; Moore et al., 1996).

Therefore, in the dyadic tests carried out in this study, this aspect may have interfered in the outcomes, as individuals that were part of distinct subgroups may have been tested together, thus, not being able to recognize each other adequately and having their behaviors not being guided by a previously stablished social hierarchy.

Such behavioral characteristics in domestic pigs may derive from the fact that pigs are animals that naturally live in small groups of familiar individuals for their whole lives, rarely interacting with individuals from a different core group (Graves, 1984; Mauget, 1981; Hafez, 1969). However, pigs under commercial settings are constantly regrouped with unfamiliar and numerous individuals (Marchant-Forde and Marchant-Forde, 2005), which instigate the fragmentation of the large group into subgroups that share space and have similar pattern use of resources (Moore et al., 1993).

5. CONCLUSIONS

A holistic view on the results obtained in this research supports the conclusion that the frequency and set of behaviors displayed near the feeder entrance (which represented the main resource in the pen) is directly correlated with the order in which sows and gilts make their first visit to the feeder in a feeding cycle. Such findings are indicators that the feeding order represents an aspect of social dominance, where dominant individuals have priority of access to the feeder and defend it from others through aggressive displays. These findings allow the validation of the feeding order as a reliable parameter for characterizing social hierarchy in a group of sows and gilts for future studies. On the other hand, the outcomes of the dyadic tests may not be an adequate parameter to identify the social hierarchy of sows and gilts housed in similar conditions to this study, and further investigation on this subject is needed.

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CHAPTER 3 – Final considerations, practical recommendations and implications

The companies and consumers requirements and the new legislations keep influencing the pig production chain to move towards better husbandry conditions for the animals, prioritizing animal welfare and challenging farms to adopt new systems and handling procedures. The tendency is that such systems will be even more important and abundant in pig production in the coming years, since pork products have an expressive demand and FAO predicts an increasing necessity of food production to meet the requirements of a fast-growing world population by 2050 (FAO, 2009).

Studies that aim to evaluate sows and gilts social aspects under group housing gestation are of essential importance regarding the rising popularity of such system worldwide. Additionally, the development of similar systems, which prioritize the welfare of animals by giving them more opportunities of exploration, freedom of movement and social interaction are not capable of bringing their full benefits unless the knowledge about complex social aspects of animal’s lives keeps growing and being applied to the commercial settings.

In-depth understanding of pig’s social behavior under free-ranging conditions, fomented by reports such as Gonyou (2001), Mauget (1981), Graves (1984) and Hafez (1969) enables the characterization of basic needs regarding the social dimension of these animals’ lives, which need to be properly regarded when housing these animals under commercial settings. Such studies are a fundamental structure and are also tools that, associated with the results of the present study, will allow a more comprehensive analysis of the dynamics of social behaviors of sows and gilts under group housing system, as well as enabling the construction of a parallel between the reported social dynamics of these animals under free-ranging conditions and the current status of this aspect regarding commercial herds.

The present study has pointed that feeding order is a proper indicator of the social hierarchy structure of group housed gilts and sows and adds to the knowledge previously brought by Bressers (1993) and Hunter et al. (1988), enabling the use of this measure as a tool in future researches and practical applications. In addition, such studies would be a great asset for understanding how these animals cope with the current technology that is being developed and disseminated in the pig industry.

However, the new technologies alone are not capable of guaranteeing a smooth functioning of the production chain. Thus, the training, capacitation and surveillance are key aspects for assuring that the best results are being achieved. Humans being in control of the social environment of domestic animals under captivity represent a great responsibility for the animal's caretakers, which reinforces the need for knowledge on the behavior of the species in order to mitigate the odds of management and handling mistakes (Baker, 1994).

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