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How social factors and behavioural strategies affect feeding and social interaction patterns in pigs

Iris J.M.M. Boumans[a,*], Imke J.M. de Boer[a], Gert Jan Hofstede[b], Eddie A.M. Bokkers[a]

[a] Animal Production Systems group, Wageningen University & Research, P.O. Box 338, Wageningen, AH 6700, The Netherlands
[b] Information Technology group, Wageningen University & Research, P.O. Box 8130, Wageningen, EW 6700, The Netherlands

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ABSTRACT

Animals living in groups compete for food resources and face food conflicts. These conflicts are affected by social factors (e.g. competition level) and behavioural strategies (e.g. avoidance). This study aimed to deepen our understanding of the complex interactions between social factors and behavioural strategies affecting feeding and social interaction patterns in animals. We focused on group-housed growing pigs, *Sus scrofa*, which typically face conflicts around the feeder, and of which patterns in various competitive environments (i.e. pig:feeder ratio) have been documented soundly. An agent-based model was developed to explore how interactions among social factors and behavioural strategies can affect various feeding and social interaction patterns differently under competitive situations. Model results show that pig and diet characteristics interact with group size and affect daily feeding patterns (e.g. feed intake and feeding time) and conflicts around the feeder. The level of competition can cause a turning point in feeding and social interaction patterns. Beyond a certain point of competition, meal-based (e.g. meal frequency) and social interaction patterns (e.g. displacements) are determined mainly by behavioural strategies. The average daily feeding time can be used to predict the group size at which this turning point occurs. Under the model's assumptions, social facilitation was relatively unimportant in the causation of behavioural patterns in pigs. To validate our model, simulated patterns were compared with empirical patterns in conventionally housed pigs. Similarities between empirical and model patterns support the model results. Our model can be used as a tool in further research for studying the effects of social factors and group dynamics on individual variation in feeding and social interaction patterns in pigs, as well as in other animal species.

1. Introduction

Living in groups is associated with competition for food resources. Competition can be low if food is widely available and high if food is scarce or an easily defendable resource. Physiological factors, such as metabolic processes and hormonal circadian rhythms that promote or inhibit food intake in animals, can increase the popularity of certain times for feeding [1]. This can increase competition for food and the risk of conflicts between animals. Furthermore, social facilitation can stimulate animals to initiate or increase feeding if another animal is feeding [2], which can further increase the risk of conflicts.

In conflict situations, animals have various behavioural strategies to gain access to food. They can show offensive behaviour and enter (approach) conflicts around food resources or show defensive behaviour to avoid these conflicts. Approaching behaviour includes fights, in which individuals can force others to leave a food resource, whereas avoidance behaviour includes a delay in entering or retreating from a conflict for a food resource. The decision of an animal to approach or avoid a conflict is affected by various factors, such as the value of the resource, the costs of a fight and the likelihood of winning [3]. The physiological state of an animal can affect this decision. A hungry animal, for example, might value a food resource more and has a higher likelihood of winning a fight for access than a less hungry animal (see review [4]). Moreover, the probability of a fight can increase when individuals have more equal chances of winning a fight (e.g. small dominance difference) and when the benefit of winning is high compared to the cost of losing a fight [5].

Variation in behavioural strategies of individuals in response to conflicts can lead to different individual feeding and social interaction patterns, such as feeding at desirable or less desirable times, more or fewer (aggressive) interactions, and feeding more or less frequently. The relation between these feeding and social interaction patterns with behavioural strategies and social factors, such as competition and social facilitation, however, is not fully understood. Understanding the mechanisms underlying behavioural patterns is of interest because it can provide insight into the variation of these patterns and the ability of

* Corresponding author.
E-mail address: iris.boumans@wur.nl (I.J.M.M. Boumans).

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animals to adapt to competitive situations. This is especially relevant for group-living domestic animals, which are not able to leave a group and have to deal with conflicts. These animals are often fed at a single location and at specific times, which can increase competition and defensive behaviour, resulting in high stress and aggression levels [6,7]. Improved knowledge about competition for food and its effect on behavioural patterns can help in preventing aggression, stress and reduced feed intake in these animals.

Optimizing performance and preventing aggression in farm animals receives much attention in research [e.g. 8–10]. Empirical studies, however, often show inconsistent results in performance and aggression and it is unclear how social factors and group dynamics affect these results [11]. Agent-based modelling can help to increase understanding of potential factors influencing behavioural patterns in animals. This modelling method lends itself particularly well for modelling group dynamics underlying behavioural patterns [12]. Agent-based modelling allows the inclusion of social interactions, individual variation and time dependent factors. Furthermore, it makes it possible to test the effect of these factors in various combinations and ranges, without the limitations of empirical studies associated with costs and use of many animals [13].

The aim of this study was to deepen our understanding of the complex interactions between social factors and behavioural strategies affecting feeding and social interaction patterns in animals by using an agent-based model (ABM) (Fig. 1). We focus in this study on pigs, *Sus scrofa.* Pigs are a typical example of animals that are often housed in fixed group sizes with one feeding place. Group size, and consequently pig:feeder ratio, can reduce accessibility to a feeding place for pigs, and therefore, increase competition and affect feeding behaviour [14]. An advantage of using domestic animals as subjects compared to wild conspecifics, is that they are suggested to have similar behavioural responses and decision-making abilities, while empirical data on their behaviour are replicable, available in larger sample sizes and less affected by confounding factors such as weather conditions or food resource differences [15].

We carried out a literature study on the development of feeding and interaction behaviour of conventionally housed growing pigs in empirical studies. Based on that study, we developed an ABM that simulates this behaviour under varying pig:feeder ratios. Pigs (agents) in the model are individually programmed and make behavioural decisions based on their own motivations and interactions with pen mates. This model builds on our previous modelling work on (1) metabolic and growth processes underlying feeding patterns during the growth period of a pig (Boumans et al. [16]), and (2) interaction between metabolic processes and hormonal circadian rhythms during a 24 hour period (Boumans et al. [17]). This ensures that in the current model, which focusses on social interactions and competition, the other elements of the pigs' behaviour, for example their hormone levels or nutritional needs, are based on first principles and have been tested separately. The model simulates effects of physiological factors, social factors and behavioural strategies on individual behaviour. This allows exploring the effect of interaction between these aspects on emergent feeding and social interaction patterns of group-housed pigs. In this paper, we first present a theoretical framework, including an overview of empirical feeding and social interaction patterns of pigs in literature and hypotheses about underlying mechanisms. Subsequently, we describe the developed ABM to test these hypotheses, analyse the model results, and discuss the findings.

1.1. Theoretical framework on feeding & social interaction patterns in pigs

A theoretical framework was constructed using pattern-oriented modelling (POM), which is a strategy to characterise the system of interest through different scales and organisational levels [18,19]. A model that simultaneously simulates various patterns similar to identified empirical patterns is expected to encompass accurate mechanisms and to be more robust in model structure and parameterisation. Based on a literature study, various empirical feeding and social interaction patterns were identified and used to design the model. These patterns and hypothesised underlying mechanisms are described in this section.

1.1.1. Feeding patterns

Feeding patterns of growing and finishing pigs with access to one feeding space (that allows one pig to feed at any time) have been studied in various group sizes (Table 1). Feeding patterns observed in these studies varied (Fig. 2), which can be a result of many factors, such as diet characteristics and breed. To avoid having to deal with these various confounding factors, our study focused mainly on the variation in feeding patters between group sizes within studies, and less on the variation in patterns between studies. Feeding patterns between group sizes show some general trends. Feed intake (g/day) remains relatively similar in all group sizes in the same study. While feeding time (min/day) decreases, feeding rate (g/min) increases with increasing group size. Meal size (g/meal/day) mainly increases in larger groups, whereas meal frequency (no/day) shows exactly an opposite pattern. Meal duration (min/meal/day) shows a pattern similar to meal size, except for the study of Walker [20], in which meal duration decreases with larger groups.

The meal-based feeding patterns (meal frequency, meal duration and meal size) seem to have a turning point around a group size of 4 to 8 [21], 8 [22] and around 10 to 15 pigs [23], after which meal patterns change direction (Fig. 2). The variation in turning point can be caused by factors, such as space availability and body weight in the specific studies.

1.1.2. Circadian distribution of feeding patterns

In both individually and group housed pigs, feed intake is usually observed in an alternans pattern, with a low level of feed intake during night and two peaks during day, with the highest peak being the second one [e.g. 23,24]. The distribution of feed intake during day time is more

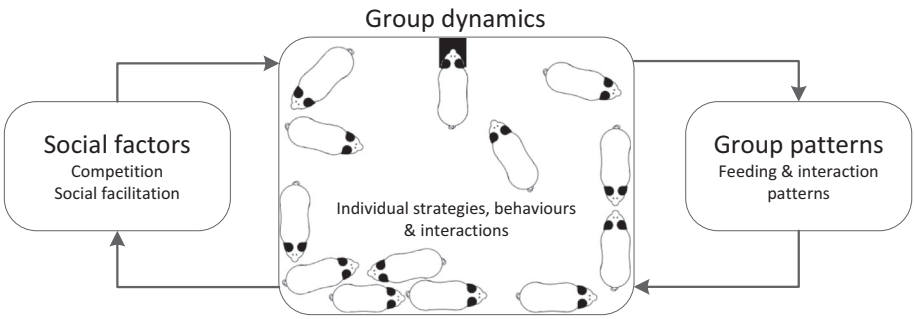

Fig. 1. Visual representation of social factors, group dynamics and behavioural group patterns in pigs included in the agent-based model.