Group sizes and resting locations of free range pigs when grazing in a natural environment

Vicente Rodríguez-Estévez a,*, Manuel Sánchez-Rodríguez a, Antonio Gustavo Gómez-Castro a, Sandra A. Edwards b

a Departamento de Producción Animal, Facultad de Veterinaria, Universidad de Córdoba, Córdoba 14071, Spain
b School of Agriculture, Food and Rural Development. Agriculture Building, University of Newcastle, Newcastle upon Tyne, NE1 7RU, United Kingdom

ARTICLE INFO

Article history:
Accepted 18 August 2010

Keywords:
Free ranging
Grazing
Iberian pig
Optimal Foraging
Social behaviour
Subgroup behaviour

ABSTRACT

A herd of 86 Iberian pigs aged 13 ± 0.5 months and with an average live weight of 110 ± 1.3 kg at the start of the study was followed to monitor their social organisation (spontaneous group size: GS) and resting preferences when free ranging on natural pastures in a dehesa of evergreen oaks (Quercus ilex rotundifolia) of 111 ha (average of 27.4 adult oaks/ha) with 2 adjacent shelters for resting. Oaks were considered as activity centres and resource patches (characterized by unpredictability in the distribution of resources). 60 complete “pig grazing days”, distributed over 6 different observation days, were studied (10 pigs per day). Every observation session was carried out for 10.5 h, covering >90% of the daylight period. Results show that pigs split into small subgroups to forage and maintained this division during daylight rests, however animals regrouped to rest during the night in a common area and behaved as a united flock. The mean daylight GS (from 9:00 to 18:00) was 8.6 ± 0.3 pigs; however GS was larger when pigs were resting than when they were grazing (13.8 ± 0.6 vs. 5.6 ± 0.3 pigs, P < 0.001). GSs were significantly different when pigs were grazing in open pasture or under an oak crown (5.0 vs. 5.8, P < 0.001). The most frequent GS when grazing under an oak were ≤4 pigs, whereas GS of pigs eating acorns was ≤2 pigs for 26.4 ± 3.0% of observations. The behaviour of these pigs could be called “Chase Optimal Foraging”, to refer to those animals which are exploiting the remains of a preferred patch (oak mast) whilst paying attention to the discovery of another close preferred patch by their group mates. When eating acorns, subgrouping would be conditioned by the space requirements to avoid competition when foraging, hence the mean grazing surface when foraging acorns could be considered an indication of the space required to avoid social stress (mean was 8.9 m² and median was 5.2 m² per pig). GSs of resting pigs increased as the day progressed. In spite of the temperature at sunset (19:00) (8.4 ± 0.1 °C outside vs. 11.9 ± 0.1 °C inside, P < 0.001), 28.6 ± 3.3% of pigs rested outside the shelters in smaller subgroups (9.5 ± 0.9 pigs outside vs. 28.0 ± 0.7 pigs inside, P < 0.001). Pigs inside each shelter constituted a single subgroup. There was no significant difference in the body weight or sex of pigs resting inside or outside the shelters at sunset. The mean surface for pigs resting inside the shelter at sunset was 6.8 ± 0.1 m² per pig. The results suggest a reconsideration of the lower critical temperature for rustic and non-lean porcine breeds, in terms of comfort and the minimum space allowance per pig for preferred resting distribution.

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1. Introduction

The social organisation of wild and feral pigs is based on a matriarchal dominance hierarchy (Spitz, 1986). A similar
dominance hierarchy is retained as the predominant means of social organisation in domestic pigs in indoor conditions, despite the artificial grouping of animals on the basis of similarity in weight and age (Turner et al., 2001). Housing pigs in large groups is also common, although the flexibility of social organisation under extreme group sizes is not fully understood (Turner et al., 2001). The current housing conditions for farmed pigs often provide a barren environment, offering little in the way of features biologically relevant to the animals, and devoid of sufficient stimulation, novelty and exploratory opportunities. More specifically, there is a lack of space and a notable absence of complexity and concealing cover, a fundamental element in natural habitats facilitating avoidance of predators and aggression from conspecifics (Leone et al., 2007). To understand how pigs behave and use the available space is crucial to both their welfare and performance. However, traditional techniques for measuring the use of space in confined pigs have been quite simple, such as calculating the proportion of individuals using different areas, called grid squares, grid cells or quadrats (e.g. Turner et al., 2003). To understand animal behaviour and welfare under intensive husbandry conditions, and to design better farm facilities and pens, it is helpful to know more about the spontaneous behaviour of free animals in natural environments. Several studies of pig behaviour have been carried out in outdoor pig production systems and seminatural environments (e.g. Stolba and Wood-Gush, 1984, 1989), but studies of traditional breeds genetically adapted to their natural environments are sparse. Hence in this research we have studied Iberian fattening pigs grazing in the natural environment for which they have evolved over many generations.

The Iberian pig is an autochthonous and non improved porcine breed traditionally raised in the southwest of the Iberian Peninsula (Spain and Portugal). Its traditional exploitation system is linked to the dehesa (Quercus ilex rotundifolia and Quercus suber open woodlands). The abundance of food provided by acorn ripening is used by the Iberian pigs during the late fattening phase, which is called montanera and takes place from early November to late February, when the diet is based only on natural resources. Rodríguez-Estévez et al. (2009a) measured a daily consumption of 7.1–8.4 kg of acorns and 2.0–2.7 kg of fresh grass; to attain such a high level of consumption, pigs seek actively the oaks with the biggest acorns (Rodríguez-Estévez et al., 2009b). This system has its own legal regulation (the Quality Standards for Iberian Pork and Cured Products), which specifies a stocking rate of <2 pigs/ha (MAPA, 2007); however the stocking rate used is lower in practice, because pigs are not allowed to receive any kind of feed or alimentary supplement and they need a great grazing area to gain the established minimum of 46 kg of weight in at least 2 months (MAPA, 2007). Hence stocking rate is typically <1 pig/ha (Rodríguez-Estévez et al., 2007).

The montanera finishing provides an opportunity to study the flexibility of social organisation of a large group of pigs at an extremely low stocking rate. In this study we considered evergreen oaks (Q. ilex rotundifolia) as activity centres, which designate the areas in which the animals spend the most time (Leone et al., 2007). We hypothesised that pigs may split into subgroups during the day and throughout the paddock in order to reduce foraging competition, according to the size and distribution of resource patches; in this sense, grazing in the dehesa would promote a spontaneous GS, with larger subgroups when pigs eat acorns than when they eat grass, because pigs should disperse throughout the paddock to reduce competition for less concentrated resources.

The aim of this paper was to study a herd of Iberian fattening pigs grazing in their natural environment to know: (i) how pigs gather to graze, (ii) how flexible is GS when pigs have the freedom of choice (iii) how pigs gather to rest, and (iv) where they prefer to rest (indoors or outdoors).

2. Materials and methods

The experimental procedures and animal care conditions were approved by the Animal Experimentation Ethical Committee of the University of Córdoba, Spain.

2.1. Area of study

The study was conducted during the montanera cycle of 2004–2005 in a dehesa of evergreen oaks (Q. ilex rotundifolia) of 111 ha with an average of 27.4 adult oaks/ha, located in Sierra Morena in the district of Fuente Obejuna (Córdoba, Spain). The study site has gentle slopes, an altitude between 600 and 680 m above sea level and a dry Mediterranean climate, there was no precipitation during any of the observation days.

Availability of natural resources was characteristic of dehesa grasslands, with the main alimentary resources being acorns and grass; acorn supply has been quantified as 8–14 kg per tree and autumnal grass production has been estimated at around 200–500 kg DM/ha (Rodríguez-Estévez et al., 2007).

2.2. Animals and handling

The study was performed using a herd of 86 Iberian pigs aged 13 ± 0.5 months and with an average live weight of 110 ± 1.3 kg at the start of the study. The adaptation regime to observers and to grazing acorns, as well as the diet and foraging behaviour of this herd, has been fully described by Rodríguez-Estévez et al. (2009a).

The experimental paddock was provided with an enclosure (night enclosure) of 1 ha to manage the pigs, with 2 straw-bedded hoop shelters of 120 m² each (15 m × 8 m) for pig accommodation. During the study, the stockman called the pigs in to the night enclosure at 18:30 in the evening before each observation day and weighing day, in order to pen all the herd to guarantee monitoring and random choice of animals marked for study. Pigs were called only on these evenings to avoid conditioning; although, according to the observations, pigs voluntarily came back to this area every night. The gate providing access to the night enclosure was closed in the evening before every observation day in order to avoid grazing activity before 8:30 and to guarantee monitoring of all the herd. This gate was opened at 8:30 for free access to the grazing paddock whenever the pigs wanted, and the enclosure remained open with free...
access during the day to permit pigs to rest inside the shelters if they chose. Once free in the experimental paddock, and during the whole period of study, pigs were allowed to graze anywhere in this area and were entirely dependent on foraged natural resources. No supplementary feed or mineral supplement was given throughout the experiment.

2.3. Measurements

2.3.1. Temperature

The temperature information inside and outside the shelters was registered with a data logger every hour during the study. For this paper temperature data were analysed only when pigs were resting.

2.3.2. Weight

Fortnightly weighing was carried out from the first day of the montanera until 2 months later. The average daily live weight gain (ADG) for each period was calculated by dividing the increase in weight during that period by the 15 days that had passed. The weighing was done in the morning, after an overnight fast, in a crate with an electronic scale (accuracy = ±0.5% of displayed weight).

2.3.3. Observation of individual and group behaviour

A team of 11 observers was trained to carry out standardised data recording under field conditions. The method of monitoring involved close and continuous observation of monitored individuals during full daytime periods without any hindrance or interruption of their spontaneous normal behaviour. Every observer used a chronometer to time grazing activity. Behaviour was analysed using scan sampling at 1 h intervals, from 9:00 to 19:00. For each monitored pig, it was recorded every hour how many animals were grazing, moving or resting in close proximity (<5 m when grazing and <1 m when resting) and simultaneously (thus behaving as a group) and the location (for definitions see Table 1).

Sixty complete “pig grazing days” distributed over 6 different observation days were studied (10 pigs per day). Every observation session was carried out for 10.5 h, starting in the morning at 8:30, half an hour after sunrise, and ending at 19:00, around sunset (thus covering >90% of the daylight period). The last registration, at 19:00, was considered as the GS for the final or night rest group. Observations started on day 10 (after 9 days adaptation to the experimental enclosure) and sampling was done every 10 days. In the evening before each observation day, when the herd was in the night enclosure, the pigs were randomly chosen and marked with colour ink spray for subsequent identification.

2.3.4. Evergreen oak crown area

In accordance with Bellot and Escarre (1989), it has been assumed that an adult evergreen oak (Q. ilex rotundifolia) has a crown spread area of 19.6 m² (2.5 m of radius). However, bearing in mind that pigs could be eating acorns at the perimeter of the oak crown area (with the body outside of the crown spread area and the head inside) and based on observations of the acorn spread, the potential oak crown area has been considered to be a larger surface of 26.2 m² (3.5 m of radius).

2.4. Statistics

The statistics software package SPSS® was used for statistical analysis. Results are expressed as mean ± SE. A Kolmogorov–Smirnov test was used to examine the normal distribution of variables. A one-way analysis of variance was used to analyse the effect of current behaviour on GS when it followed a normal distribution. When GS did not follow a normal distribution, the non-parametric Mann–Whitney U test was used to compare the differences between behaviours.

3. Results

3.1. Group sizes

The mean daylight GS was larger when pigs were resting than when they were grazing (13.8 ± 0.6 vs. 5.6 ± 0.3 pigs, P < 0.001). In consequence, GS increased as the day progressed due to the increasing number of pigs resting and the associated regrouping.

Fig. 1(A and B) shows the daily GS distribution when pigs were grazing acorns or grass, respectively. GS when pigs were eating acorns decreased slowly over the day as the number of active pigs decreased. GS when pigs were grazing grass was very variable across the day. GSs were significantly different when pigs were grazing outside (grass) or under an oak crown (acorns) (Table 2).

When pigs were grazing under an oak, GS did not differ significantly between the first (November) or the second
Fig. 1. Evolution of group size during the grazing day for pigs which are eating acorns under 1 oak crowns (A) or grazing grass (B). The box shows mean, Q1, Q3, min and max.

Table 2
Grazing and resting group size during the daylight observations (excluding sunset observation); mean ± SE.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Place</th>
<th>n</th>
<th>Group size (number of pigs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>Outside an oak crown</td>
<td>84</td>
<td>5.0 ± 0.6a</td>
</tr>
<tr>
<td></td>
<td>Under oak crown</td>
<td>295</td>
<td>5.8 ± 0.3b</td>
</tr>
<tr>
<td>Resting</td>
<td>Outside</td>
<td>80</td>
<td>6.2 ± 0.54a</td>
</tr>
<tr>
<td></td>
<td>Inside the hoop shelter</td>
<td>141</td>
<td>17.9 ± 0.6b</td>
</tr>
</tbody>
</table>

Within each group, means with different letters are significantly different P<0.001.

(December) fattening month (6.0 vs. 5.5, P=0.33). Fig. 2 shows the frequency distribution of GS when grazing under an oak; the frequency of GSs ≤4 pigs was 48.5%, GS≤2 was 25.8±3.0% and the most frequent GS was 1 pig. However, 25% of pigs studied were never observed in a GS ≤2 pigs.

There was a significant difference in the daylight resting GS (from 9:00 to 18:00) depending on the resting place.

Fig. 2. Cumulative frequency of group size when pigs were eating acorns (under oak crowns).
Table 3
Average temperature inside and outside the shelters when pigs were resting (°C); means ± SE.

<table>
<thead>
<tr>
<th>Light</th>
<th>Hour</th>
<th>Daylight</th>
<th>After sunset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14:00</td>
<td>15:00</td>
<td>16:00</td>
</tr>
<tr>
<td>T outside</td>
<td>17.6 ± 0.2</td>
<td>12.8 ± 0.2</td>
<td>11.9 ± 0.1</td>
</tr>
<tr>
<td>T inside</td>
<td>13.3 ± 0.4</td>
<td>12.8 ± 0.2</td>
<td>12.4 ± 0.2</td>
</tr>
<tr>
<td>Difference</td>
<td>4.3 ± 0.3</td>
<td>0</td>
<td>−0.5 ± 0.5</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(Table 3). Fig. 3 shows that while GS tended to increase as the day progressed when pigs rested inside the shelters, it remained more or less constant when they rested outside. Pigs started to rest in the shelters at 14:00, when the mean temperature difference between inside and outside was −4.3 °C (Table 3). However, 2 h later (at 16:00) inside temperature began to be significantly higher than outside and after sunset (at 19:00) the temperature difference between inside and outside was 3.5 °C.

GSs of resting pigs at sunset were 9.5 ± 0.9 pigs outside and 28.0 ± 0.7 pigs inside the shelters (P < 0.001). Pigs inside each shelter constituted a single subgroup.

3.2. Space allowance and place for resting

Table 4 shows the space utilisation when pigs were foraging acorns, considering the potential crown area and assuming that all the pigs were eating acorns inside the crown spread area and around its perimeter. The mean was 8.9 m² per pig; however the median, which was 5.2 m² per pig, was much lower.

All the monitored focal pigs went back voluntarily to the night enclosure for resting. However, 28.6 ± 3.3% of them (minimum 18.6 and maximum 39.5%) were resting outside the shelters at sunset (19:00). The resulting mean surface for resting inside the shelter was 6.8 ± 0.1 m² per pig (minimum was 5.1 and maximum was 8.3 m²). Unexpectedly, the minimum resting surface indoors did not correspond to the lower temperature day, and pigs were not huddling at this temperature (6.2 °C indoors). Table 4 shows average temperature inside and outside the shelters when pigs were resting.

There were no significant differences in the body weight (132.5 ± 2.9 kg inside vs. 140.3 ± 3.5 kg outside, P=0.11)

Table 4
Average surface per grazing pig when they are eating acorns (m²).

<table>
<thead>
<tr>
<th></th>
<th>Under crown spread area</th>
<th>Under potential crown area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SE</td>
<td>6.6 ± 0.3</td>
<td>8.9 ± 0.5</td>
</tr>
<tr>
<td>Percentile 25</td>
<td>2.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Percentile 50</td>
<td>3.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Percentile 75</td>
<td>9.8</td>
<td>13.1</td>
</tr>
</tbody>
</table>

a Evergreen oak crown spread area = 19.6 m² (Bellot and Escarre, 1989).
b Evergreen oak potential crown area to eat acorns = 26.2 m².
nor in the gender of pigs resting inside or outside the shelters at sunset (65.7 ± 8.3% of males inside vs. 66.7 ± 11.4% of females).

4. Discussion

4.1. Group size when foraging

Maintenance of a dominance hierarchy requires an ability to discriminate between individual group members and the establishment and periodic reinforcement of dominance relationships (Turner et al., 2001), a large group size is likely to impede these abilities (Turner et al., 2003). Hence, to obviate the effects of a large group size it has been hypothesised that there is spatial sub-division of the group into smaller subgroups in which an efficient dominance hierarchy may be preserved among individuals in regular proximity (Oden et al., 2000). The use of such strategies may vary between groups, between individuals within a group and over time (Turner et al., 2003). Reducing the effective group size can be achieved by two approaches: (i) by remaining only in a restricted area and (ii) by preferentially associating close to specific individuals, irrespective of their location (Turner et al., 2003).

The sub-division of the herd into subgroups suggests that, under natural conditions, attributes of the pigs themselves may dictate space use, inter-individual distances between animals and demographic units. GS or herd size also depends on natural resources availability (Maugé, 1981; Graves, 1984), therefore masting season and its associated superabundance of food resources (Rodríguez-Estévez et al., 2007) would favour a large GS. However, foraging in the dehesa during the acorn masting is a complex situation because natural resources (food) are distributed in different ways: acorns are distributed in patches (aggregated) whereas grass has a wider distribution. Foraging (search) costs would be modified by the way food resources are distributed (dispersed or aggregated) and the extent to which animals are able to exploit this opportunity spatially (Parsons and Dumont, 2003). Also it is necessary to bear in mind that acorn weight, size, shape and composition vary a great deal among evergreen oaks (Quercus ilex rotundifolia) (Rodríguez-Estévez et al., 2008, 2009b). In consequence, evergreen oaks become patches with very different resource levels due to two reasons: (i) their acorns are different (Rodríguez-Estévez et al., 2008, 2009b) and (ii) the amount of acorns varies through the season because of the selective consumption by the pigs (Rodríguez-Estévez et al., 2008) and because acorns drop from the trees progressively, which leads to a process of renewal in the supply (Rodríguez-Estévez et al., 2007). Hence patch quality can vary as a consequence of foraging by intra- and interspecific competitors.

When food is distributed patchily, the expected rate of encounter with the patches is far greater where there are more smaller patches than with fewer larger ones (Parsons and Dumont, 2003). The mean mast of an evergreen oak is 8–14 kg of acorns per tree, although among the tree mass there are oaks without production (Rodríguez-Estévez et al., 2007) and a pig has a daily selective consumption of 7.1–8.4 kg of acorns (Rodríguez-Estévez et al., 2009a). However, the previously mentioned variation in the amount of acorns makes it difficult to achieve the daily consumption of acorns under a few trees; in fact pigs obtain their daily acorn consumption after having walked an average of 3.9 km in 6.1 h of grazing activity (Rodríguez-Estévez et al., 2010) to visit an average of 97.2 evergreen oaks where they eat at least one acorn (Rodríguez-Estévez et al., 2005).

It could be considered that there are very small additional search costs for foraging acorns when pigs move to a new evergreen oak leaving mast under the previous one (Rodríguez-Estévez et al., 2009b), because trees are rather close in the dehesa (27.4 trees/ha in the studied tract of land) and there is always a potential foraging advantage under the next tree.

The mast patches (crown spread areas) are a case where the distribution of food items is not detectable at a distance (neither visual or olfactory cues are available for locating them). In this case, learning and spatial memory become potentially more valuable (Parsons and Dumont, 2003). However, in an homogeneous and savannah-like landscape there are few clues to go back to oaks with preferred acorns (Rodríguez-Estévez et al., 2009a). Animals foraging within a group benefit from the feeding sites (e.g. oaks with preferred acorns) discovered by other members of the group and from shared vigilance, but they can face the negative effects of intra-specific competition for food within the food patches (Mendl and Held, 2001; Parsons and Dumont, 2003). As expected, the GS found was larger when pigs were eating acorns than when eating grass. Hence, according to evolutionary theory (Mendl and Held, 2001), which explains the balance of competitive and cooperative behaviour between group members, we could establish that GS when eating acorns is the most suitable one for pigs in terms of balancing competition and cooperation.

It has been modelled for sheep that in an unfamiliar and complex environment, where the cost of finding preferred food items is high, that the foraging success of an animal decreased together with the increase in conspecific attraction within the group (Dumont and Hill, 2001). This would be the situation at the end of the masting season when favourite acorns (the heaviest and largest) have run out (Rodríguez-Estévez et al., 2008). However, contrary to expectation, GS when pigs were eating acorns remained relatively constant across the season; the abundance or shortage of acorns did not have any influence on GS. This might be because pigs would need more cooperation than before to share their skills when selecting oak masts to detect other characteristics in the acorns. Regarding this issue, Rodríguez-Estévez et al. (2008) found differences in the pigs’ criterion to reject or to consume the acorns from an oak at the beginning and at the end of the montanera fattening period; corresponding to the kernel weight and to the kernel composition respectively.

According to the theory of Optimal Foraging (Emlen, 1966), animals try to maximise their net rate of energy intake per unit time through the selection of their food intake. Thus pigs should leave preferred oaks before exploiting all the mast these trees contain (Marginal Value Theorem). There is a theoretical optimal time to leave a patch, which is modified by the rate of depletion of the...
current patch and the time spent reaching the next patch (Stephens and Krebs, 1986). On the other hand, Beauchamp and Girard (1997) found that when several food patches are available, exploitable birds may respond to the arrival of scrounger foragers by leaving their food patches, and moving to another patch even if the first one is not completely depleted. In the dehesa, the adult tree density is high and there is a high probability of finding a close preferred oak. The high frequency of a group size of ≤2 suggests a further strategy which could be called “Chase Optimal Foraging”, to refer to those animals which are exploiting the remains of a preferred patch (oak mast) while they are paying attention to the discovery of another close preferred patch by their group mates. This discovery would be easily detected through spatio-temporal clues, due to the fact that Iberian pigs eat an average of 3.2–3.7 acorns per visit under the rejected oaks and an average of 117.3–128.8 acorns per visit under the preferred ones (Rodríguez-Estévez et al., 2009b). Held et al. (2010) suggest the ability to discriminate between different individual co-foragers in domestic pigs, and increasing foraging speed as a way of responding to exploitation by scrounging dominants in competitive foraging situations with several food patches; however in the present study a high frequency of “chase foragers” was found and this could suggest that when pigs are eating acorns the scrounging role could be shared. Held et al. (2002) indicate that subordinate pigs respond to exploitation by flexibly adjusting their foraging behaviour to the current behaviour of dominants. “Chase Optimal Foraging” behaviour would compensate for the reduction in food intake rate when group foraging for patchily distributed food compared to a solitary forager, as has been proposed by Valone (1993), and would also be a mechanism for the balance of competitive and cooperative behaviour that occurs between group members; gaining advantages from both solitary and group grazing. Besides, “Chase Optimal Foraging” behaviour would be a useful strategy to exploit the remaining acorns of preferred patches in a highly homogeneous environment where using spatial memory would be difficult. Investing time in exploring patches to determine their quality may reduce the cost of feeding in a low-quantity patch where a high-quality alternative could be available. However, exploiting the exploration time of others, and the resulting reduction in search time, could be an important benefit of group living, particularly for animals relying on food that is distributed unpredictably in space or time (Mendl and Held, 2001).

Stolba and Wood-Gush (1989) state that during grazing the minimum distance between groups is 50 m. Social groups keep their cohesion in spite of the concentration of food resources in specific areas (Graves, 1984). Although we did not study the distance between subgroups during foraging we have found different subgroups foraging under adjacent trees; however at other times the followed subgroup completely lost visual contact with other subgroups.

When eating acorns, subgrouping would be conditioned by the space requirements to avoid competition when foraging. Hence the mean grazing surface when foraging acorns could be considered as the minimum necessary space to avoid social stress. Also, due to the maintenance of smaller GS when grazing grass (without any space limitations), it could be suggested that the GS observed would be the ideal GS for fattening pigs from a natural behaviour point of view. Furthermore, Rosell et al. (2004) found a similar mean GS when studying the social organisation of wild boar (Sus scrofa, L.) in a Mediterranean marshland (5.5 individuals per group in autumn and 4.4 across the whole year).

4.2. Group size when resting

Regrouping for resting showed a circadian rhythm and, although these pigs did not have any predators, this behaviour (larger resting GS) could have been favoured by the advantage of an easier vigilance (alertness or watchfulness) in large groups because animals in larger groups gain greater protection from predators than those in smaller groups (Caraco, 1981; Clark and Mangel, 1984; Pulliam and Caraco, 1984). Differences could also be due to heat conservation reasons at some times of day, as 2 h after clustering inside the hoops, environmental temperature was higher than outside.

Turner et al. (2003) suggest that pigs in smaller groups could be more likely to demonstrate affinities for other group members than their counterparts in larger groups. According to this suggestion it could be theorized that socially inferior individuals could feel more comfortable gathering in smaller groups to rest outside than competing for a location inside the shelters with a large group of mates. Also, it could explain why pigs go to the night enclosure for the night rest (final rest) but they do not go into the shelter from the beginning of the rest period. These suggestions would require more detailed investigation before valid conclusions could be drawn, but are not supported by the lack of weight and gender differences between the inside and outside populations.

In a larger group, dominance hierarchy may be preserved by subgrouping, and this could be achieved by spatial localisation, as indicated by the existence of preferred resting locations (Turner et al., 2003). They propose that under intensive and indoor conditions, location based subgrouping is likely to be seen only during resting, since the location of key resources such as food and water requires animals to visit certain areas periodically. The situation in the evening for the pigs studied would be similar, animals would go back to the night enclosure and regroup while subgrouping for resting.

4.3. Place for resting

The free range pigs studied split into subgroups for foraging. However they returned to a common area for resting where they maintained a subgrouping behaviour, this was especially evident in the smaller groups resting outside the shelters. Turner et al. (2003) found the existence of and affinity to preferred resting locations and dependency between individuals in their choice of resting locations when they investigated growing pigs housed indoors in groups of 20 and 80; but they found that clustering around the mean location was more dispersed in the larger groups and little evidence was found in the larger groups for dependency between individuals in their choice of resting.
locations. Durrell et al. (2004) suggest that unrelated pigs are capable of forming preferential associations, although it is unclear whether such associations are widespread or important to pigs.

In a natural or seminatural environment, the preference for the same resting location would be conditioned by its favourable conditions. In this sense, when studying the foraging behaviour of this same herd, Rodríguez-Estévez et al. (2009a) mention that the return to the night enclosure could be conditioned by the lack of water in the field. In addition, the shelters could be considered as places to take refuge or hide from predators, bearing in mind the lack of dense shrubs in the dehesa landscape. In this sense, Cargnelutti et al. (1995), when studying wild boar in all landscapes, found that the resting places were preferentially located in environments with dense vegetation.

Pigs rested outside the shelters while solar irradiance was high (until 16:00) in spite of the higher temperature inside the shelters. Later, pigs showed a clear preference for resting inside the shelters because animals resting outside were moving into the shelters as the afternoon progressed. The difference in temperature between inside and outside the shelter was low, however the animals tend to spend most time in the place of lowest air movement (Ingram and Legge, 1970) because thermal environment outdoors is influenced by the effects of radiation and wind (McArthur, 1990). Nevertheless, there was a high percentage of pigs resting outside the shelters at sunset when temperature was below the lower critical temperature, calculated for these animals as 18.7 °C (Bruce and Clark, 1979), based on the estimated energy balance of this herd (Rodríguez-Estévez et al., 2010). This behaviour reduces the feed efficiency because pigs in groups need 1.9–2.4 kcal of ME per kg LW0.75 per degree below the lower critical temperature (ARC, 1981). Ingram and Legge (1970), observing groups of young pigs while confined to an area which included both woodland and open pasture as well as a hut with straw bedding, found that these pigs did not begin to shelter and huddle together in the hut until ambient temperature was below 5 °C. The ability of pigs to cope with ambient temperature depends among other things on their weight, and tolerance of low temperatures rises with increasing weight (Botermans and Andersson, 1995; Hillmann et al., 2004). The subcutaneous back fat would contribute to insulate pigs from low environmental temperature; e.g. Forero Vizcaíno (1999) found 8.6 cm of subcutaneous back fat for finished Iberian pigs of this variety at slaughter after montanera.

The same GS at sunset inside both shelters could be explained by the need for space. Pigs would have been willing to share the inside space up to a limit. Extreme ambient temperatures may lead to competition for preferred lying places among the pigs and to a state of discomfort in pigs which failed to find an adequate lying place or which are disturbed in their resting behaviour by others; although according to Fraser (1985), pigs move in concert and large behavioural differences are observed between groups with respect to air temperature and floor bedding.

Body weight or gender of Iberian pigs studied, as possible indicators of dominance, did not explain the place for final resting. Resting place was not influenced by pig gender or weight, as was found previously by Turner et al. (2003), and this indicates that resting locations were chosen independently of these attributes. The place for final or night rest could be explained by the existence of preferred resting locations (outside or inside the shelters), as has been described previously for large groups of indoor housed pigs observed several weeks after group formation when integration should be complete (e.g. sows, Edwards et al., 1986; young pigs, Penny et al., 1997).

Pigs studied were randomly chosen and no information on the identity of subgroup mates was registered, hence it is not possible to obtain more information from this study. However, on this matter, Turner et al. (2003) found that pigs which have shared a common pen before being regrouped do not locate in a specific area of the new pen and do not show a reduced inter-individual distance compared to pigs from different pens.

We have to emphasize that regrouping for rest and subgrouping behaviour clearly was a strategy adopted by the whole pig herd. In spite of the unlimited space available for segregation, the pigs shared a common resting area inside the shelters and around these in the night enclosure, where the gate remained open. The existence of a common resting area for all the sows of a herd and their piglets has been described previously by Jensen (1986) and Stolba and Wood-Gush (1989) in a free ranging seminatural environment. As Turner et al. (2003) propose, the phenotypic similarity of the animals might have inhibited the emergence of different demographic groups. However, it is unknown whether an individual chooses to locate in an area because of the proximity of specific group members and whether the decision to locate close to another pig is made with reference to physical and social attributes such as weight, gender or historic familiarity (Turner et al., 2003).

5. Conclusion

Pigs split into small subgroups to forage and keep this division during daylight rests. However animals regroup to rest during the night in a common area and behave as united flock. In this sense large groups that are used in intensive farms could be considered natural under non-overcrowding conditions. However the proportion of pigs resting outside the shelters at sunset suggests further detailed study of: (i) the lower critical temperature for rustic and non-lean porcine breeds, in terms of comfort and (ii) the minimum space allowance per pig for animal welfare. These points may provide more data to explain the reason for resting outside the shelters in spite of the low environmental temperature. It is unclear whether the resting location is conditioned either by the shelter protection from weather and predators, as a replacement for the lack of forest to take refuge in the dehesa, or by the water proximity.

It could be suggested that the observed GS when eating acorns is the most suitable one for pigs in terms of balancing competition and cooperation. Therefore the mean grazing surface when foraging acorns (8.9 m²/pig) could be considered as the minimum necessary space to avoid social stress. Also the smaller GS when grazing grass (without any space limitations) suggests that the GS found (n = 5 ± 0.6) could...
be considered the ideal GS for fattening pigs from a natural behaviour point of view.

We have discussed some basic features of the animals’ behaviour, given heterogeneous and spatially distributed food, which includes the benefits and costs of social interactions when foraging as a group. Study of the pigs’ selective capacity for learning and spatial memory when grazing individually would be interesting, to avoid problems arising from imitation and competition within the subgroup and the herd. Also, further research is need in order to study in more detail: (i) the “Chase Optimal Foraging” strategy to know if it is a cooperative behaviour (shared and followed successively by all the subgroup mates); (ii) what is the number of foragers that are likely to take the patch leaving decision (random animals or a specific group leader); (iii) the consistency of subgroup membership; (iv) and finally, if there is any individual tendency to individualism or gregariousness when grazing or eating.

Acknowledgments

We thank Turcañada S.L. for its invaluable technical support and collaboration. This research was funded by Dirección General de la Producción Agraria y Ganadería of Consejería de Agricultura y Pesca of Junta de Andalucía.

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