Foraging of Iberian fattening pigs grazing natural pasture in the dehesa

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Abstract

Two different herds of Iberian pigs have been studied in the montanera fattening period (from November first to end of December) in the dehesa agrosystem (clear forest of evergreen oaks, Quercus rotundifolia) during two different autumns and winters (2003 and 2004) without any supplementary feed. A direct in situ observation method has been used, with continuous observation of ingestive bites taken by continuously monitored pigs (10 uninterrupted hours, from 08:30 to 18:30) to calculate intake. 95 grazing days have been studied corresponding to different randomly chosen pigs. The obtained results show grass and acorns as the main resources with 56.5 and 43.3% of bites respectively. 14 other resources different from grass and acorns were registered, but only 9 resources (berries, bushes, inorganic rubbish, woods, roots, earth and sand, charcoal and ashes, carrion and straw) were consumed at a frequency ≥0.01%. The percentage distribution for daily bites showed no significant difference between years. However daily grazing times were significantly affected by year, and were associated with available drinking water from rain. Lack of water in second montanera forced pigs to return to shelters to drink and, in consequence, reduced daily mean grazing time (from 427±21 min in montanera 1 to 368±8 in montanera 2; P<0.001) and kernel acorn dry matter intake (from 3.6±0.3 kg in montanera 1 to 3.1±0.1 in montanera 2; P<0.05); however, it did not significantly influence either daily grass dry matter intake (0.38±0.04 kg in montanera 1 versus 0.49±0.04 kg in montanera 2) or total daily dry matter intake calculated from bite number (4.0±0.3 kg in montanera 1 versus 3.6±0.1 in montanera 2).

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1. Introduction

Legal trends and consumer demands related to animal welfare, alimentary security, environmental protection, etc. have generated an interest in outdoor swine production systems (Edwards, 2005). The growing number of pigs kept outdoors has renewed interest in their nutrient requirements under these conditions, and the contribution that might be made to these requirements by grazing (Edwards, 2003). Works mainly study grass consumption by outdoor adult pigs fed with concentrates (Close, 1993; Rivera Ferre et al., 2001; Sehested et al., 2000; Santos Ricalde and Lean, 2001; Edwards, 2003) but data on grazing herbage intake of growing pigs are very scarce (Edwards, 2003; Stern and Andresen, 2003) and there are no known studies covering their complete omnivorous diet grazing natural pastures. Different authors mention a wide range of resources consumed by pigs (Aparicio Macarro, 1988;
López Bote et al., 2001). Stolba and Wood-Gush (1989) described the behaviour of domestic pigs in a semi natural environment but there is no known research dealing with the free grazing diet of domestic pigs in a natural environment without any supplementary feed.

The Iberian pig is an autochthonous porcine breed developed traditionally in the southwest of the Iberian Peninsula (Spain and Portugal). Its traditional exploitation system is linked to the “dehesa” (Quercus ilex rotundifolia and Q. suber open woodlands) during the late fattening phase, using the abundance of food provided by acorn ripening, which is called “montanera” and takes place from early November to late February. This system has its own legal national regulation (MAPA, 2007).

It is well known that Iberian pig montanera diet is based on acorns and grass (Aparicio Macarro, 1988; Lopez-Bote, 1998). This system is of great interest due to the differentiating characteristics it contributes both to the carcasses and the products derived from them (Lopez-Bote, 1998). Recent studies mainly focus on the influence of acorns on the fatty acid composition of the adipose tissues of its carcass (e.g. Cava et al., 1999; Ruiz et al., 1998). However, there is a lack of studies about the grazing behaviour of this breed, its use of natural resources and the ingested proportions of acorns and grass. Previous ingestion estimations are rather crude, for instance Dobao et al. (1988) proposed an acorn ingestion of 6–10 kg and 1–1.5 kg grass daily. However, if we are to make the most efficient use of the available natural resources, it is essential to improve our understanding of the foraging strategies of livestock which use the ecosystems.

The purpose of the present study is to determine the daily grazing time, the components of diet, the voluntary intake and the nutrient balance obtained by finishing Iberian pigs grazing in the dehesa pastures during the montanera period without any supplementary feed.

2. Materials and methods

2.1. Area of study

The study site is a dehesa area located on the Northwest of the Córdoba province (Southern Spain) with dry Mediterranean climate, mean annual precipitation of 514 mm and mean annual temperature of 16.1 °C (18.8 °C and 9 °C mean of maximum and minimum temperatures respectively) (De León Llamazares, 1989). Soils are siliceous and sandy, constituted by southern brown-earths and rankers on granite (González Garcia, 1971). The area has an altitude between 600 and 680 m above sea level and is characterized by a undulating topography furrowed by seasonal water courses.

Botanically the area is considered as Durilignosa formation (De León Llamazares, 1989) and its potential vegetation corresponds to the climax dominion Piro-Quercetum rotundifolii fagineosum (González García, 1971). The grazing surface is a “dehesa” with 27.4 adult and productive evergreen oaks (Quercus rotundifolia) per hectare, and small areas with shrubs: Cistus monspeliensis, C. salviifolius, Retama sphaerocarpa, Lavandula stoechas, Thymus zygis, etc. Grassland includes mainly: Agrostis sp., Poa bulbosa, Trifolium subterraneum, T. arvense, T. cherleri, T. stellatum, Ornithopus sp., Diplolaxis sp., Echium plantagineum, Erodium sp., Chamaemelium mixtum, Senecio vulgaris and Diplolaxis sp.

2.2. Date of trials

The same study has been carried out on two consecutive montaneras: Montanera 1 (M1, since November first 2003 to end of December 2003) and Montanera 2 (M2, since November first 2004 to end of December 2004).

2.3. Animals

This study has been carried out with one herd of 84 purebred Iberian fattening pigs studied in each year, being the progeny in successive years of the same outdoor breeding herd. Pigs were of both sexes and had a live weight of 113.4±1.1 and 110.2±1.3 kg at the start of the study, respectively for M1 and M2. All pigs were castrated under anaesthesia after weaning, following the Spanish regulations and with the supervision of University of Córdoba Ethical Committee, to work with the same kind of pigs of the traditional “montanera” system.

Pigs were dewormed and nose-ringed a month before moving to the experimental paddock. Rings were made from flexible copper and clipped through the upper rim of the snout.

2.4. Animal familiarisation

A familiarisation procedure was used to accustom the animals to having an observer very close to them and to learn moving between foraging pigs without disturbing them. Since the pigs weighed 20 kg they were fed with supplementary feed on the floor while the stockman stayed walking between the flock.

During 30 days, since October first, the flock grazed in an adaptation enclosure of 10 ha of dehesa beside the experimental paddock, receiving a daily commercial feed ration of 500 g each.

2.5. Housing, feeding and management during trials

The experimental paddock had 111 ha and was provided with an enclosure (night enclosure) of 1 ha with 2 hoop shelters for pig accommodation (1.5 m²/pig) to manage the pigs. The night enclosure remained open with free access during the day to permit pigs resting inside the shelters. Pigs had free access to a water trough inside the night enclosure. Pigs could also drink in puddles and small temporal streams along the experimental paddock.

Once free in the experimental paddock and, during the whole period of study, pigs were only allowed to graze in this area and were entirely dependent on foraged food. No supplementary feed was given throughout the experiment,
nor did they receive any supplement of salt licks and minerals at night in the night paddock. The adaptation period to graze only natural resources was during the 9 days before the observations began at day 10.

Availability of natural resources was characteristic of dehesa grasslands, with the main alimentary resources being acorn and grass.

3. Measurements

3.1. Meteorology

The meteorology information has been provided by a very close meteorological station (approximately 5 km away) and at the same altitude. Mean, minimum and maximum temperature and precipitations have been registered daily since the 1st September to the 1st of January during both trials.

3.2. Observation of individual grazing behaviour

To choose a team of 11 observers, a group of 30 volunteers were previously standardised for recording, trained under field conditions and tested with several video recordings to recruit the most skilful. The observers followed the monitored animals for the whole day at a distance of approximately 1–3 m, remaining alongside the animal so as not to obstruct their spontaneous line of movement, in order to continuously observe their mouths, listen to pigs chewing and to identify bite categories. Every observer used a chronometer to time grazing activity and to register the beginning hour of the final rest.

Every observation session was carried out for 10 h, starting in the morning at 8:30, half an hour after sunrise, and ended at 18:30, around sunset (covering 90% of daylight period). The gate to access the night enclosure was closed the evening before every observation day in order to avoid grazing before 8:30 and to guarantee no grazing intake without monitoring. This gate was opened at 8:30 for free access to the grazing paddock whenever the pigs wanted.

Observations started on day 10 (after 9 days in the experimental enclosure) and sampling was done every ten days. In the evening before each observation day, while pigs were resting in the night enclosure, four to eleven pigs a day within the herd were randomly chosen and colour ink spray marked for later observation. Both sexes were homogeneously distributed in the sampled population of each year (15 males and 19 females in M1 versus 33 males and 28 females in M2).

The method of monitoring has been close, continuous, focal and detailed observation of grazing activity and ingestive bites taken by continuously monitored individuals during full daytime periods without any interruption and with freedom to express normal behaviour and spontaneous feeding motivation.

In M1, 34 complete grazing days were analysed, distributed in 7 different observation days and in M2, 61 complete grazing days distributed in 6 different observation days. A grazing day corresponds to a randomly chosen pig.

3.3. Foods and intake recording

Prior to the observation period there were several sampling observations in the experimental paddock, in order to identify and classify all possible bite types carried out by the pigs. According to this sampling and to the bibliography, the different bites were subsequently separated into 3 bite groups (“acorn”, “grass” and “other”) and 14 bite categories within the “other” group, based on the kind of food resource, the shape, size and part selected (Table 2).

A bite has been defined as: a) either a visible or audible indication that an animal had severed material from a plant (Ganskopp and Cruz, 1999); b) the act of breaking off or picking up a piece of any resource; c) the act of picking up, cracking and shelling an acorn. After having observed Iberian pigs only take one acorn each time, to distinguish the consumption of an acorn there are 4 consecutive clues: 1st the pig takes the acorn and this disappears; 2nd the pig cracks the acorn and it is possible to hear the cracking; 3rd the pig stops sniffing and chews the acorn; 4th the pig spits out the shell and carries on chewing the acorn. In this respect, acoustic analysis of grazing behaviour was found to allow accurate identification of chewing and biting, and estimation of intake (Laca et al., 1994; Laca and Wallis Devries, 2000).

As it was expected that a high amount of bites of acorns and grass were to be taken, to count both kinds of bites every observer used two manual counters, one to count the consumed acorns and the other for bites of grass. The two counters were differentiated with colour tapes. The observers recorded each bite of grass or acorns by pressing the respective manual counter and writing down on a clipboard with a data sheet all the other bites. Thus, during the observation period, everything that the animal fed on was noted.

3.4. Intake per bite and sample collection

Grass intake per bite was quantified by grouping all herbaceous species in a single class according to the methodology used to quantified small ruminants intake (Peinado-Lucena et al., 1992). Weight per mouthful was
estimated by manual simulation of grazing (hand-plucked) adapting to a pig bite by imitating the behaviour of pigs (clipping material physically comparable to that selected by the animals) and following the hand clipping method as described by Meuret et al. (1985) by dividing the weight of 20 samples collected at 10 different places into the number of bites (200). Furthermore, 10 samples of 1000 g of grass were collected at the same places to analyse chemical composition. This sampling was done after the first studied grazing day in M1 along the areas where pigs had grazed. Additionally, at the start of the study in M1, a sample of 2000 acorns from 100 evergreen oaks (20 acorns per tree) randomly chosen was collected to quantify acorn intake per bite. The acorns were individually weighed with and without shell before drying their endocarp. 20 samples of 250 g of acorns corresponding to other 20 oaks randomly chosen were also chemically analysed. Determination of the compositional analysis of samples of grass and acorn endocarps (DM, ash, crude fibre, crude protein, crude fat and nitrogen free extractives) was carried out according to AOAC (2000) methods. Daily DM consumed was determined on the basis of the number of bites and the weight of DM per bite. The first year composition of acorn and grass has been assumed for the second year according to previous authors (e.g. Cava et al., 1999; Ruiz et al., 1998), who consider a homogeneous acorn and grass composition along montaneras, and according to Fernández et al. (2005) who, analysing acorns from the same trees of several geographical areas to study compositional differences between years, found that the most significant is the existing geographical variability, and according to Medina Blanco (1956), who analysed autumnal and winter grass in the dehesa area.

### 3.5. Drinking records

Drinking or a drink act have been considered as every time the pig introduces its mouth into the water to drink (snout contact with water) and makes sucking noises. To avoid any mistake by considering a bout of drinking (sequence of continuous drinkings) as different drinking sequences, these have been separated and analysed

### Table 1
Climate parameters over the study periods

<table>
<thead>
<tr>
<th>Climate parameter</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulate precipitation between 1/9 and 31/10 (mm/m²)</td>
<td>217.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>146.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total precipitation during the study periods (between 1/11 and 30/12)</td>
<td>187.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.8&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Number of days with precipitation &gt;0.2 mm/day during the study periods (between 1/11 and 30/12)</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>Mean precipitation of days with any precipitation during the study periods (between 1/11 and 30/12)</td>
<td>5.22±1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.06±0.45&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean temperature during the study periods (between 1/11 and 30/12)</td>
<td>9.3±0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.81±0.33&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Within each group, means with different letters are significantly different (P<0.05).

### Table 2
Number and percentage of daily bites and frequency distribution of all types of bites registered in both montaneras during 10 h of observation; mean±S.E.

<table>
<thead>
<tr>
<th>Category of bite</th>
<th>M1</th>
<th>% of bites</th>
<th>M2</th>
<th>% of bites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of bites</td>
<td></td>
<td>Number of bites</td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>1451±149</td>
<td>47.2±2.8</td>
<td>1893±158</td>
<td>54.1±2.3</td>
</tr>
<tr>
<td>Acorns</td>
<td>1469±111&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.5±2.8</td>
<td>1251±42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.5±2.3</td>
</tr>
<tr>
<td>Other resources</td>
<td>7.1±1.8</td>
<td>0.2±0.05</td>
<td>7.8±1.5</td>
<td>0.3±0.1</td>
</tr>
<tr>
<td>- Berries</td>
<td>0</td>
<td>0</td>
<td>2.4±0.9</td>
<td>0.1±0.04</td>
</tr>
<tr>
<td>- Bushes</td>
<td>0.9±0.5</td>
<td>0.03±0.02</td>
<td>1.3±0.3</td>
<td>0.05±0.02</td>
</tr>
<tr>
<td>- Inorganic rubbish</td>
<td>1.5±0.5</td>
<td>0.05±0.01</td>
<td>0.9±0.2</td>
<td>0.04±0.01</td>
</tr>
<tr>
<td>- Woods</td>
<td>1.0±0.3</td>
<td>0.04±0.01</td>
<td>0.8±0.2</td>
<td>0.04±0.01</td>
</tr>
<tr>
<td>- Roots</td>
<td>1.3±0.6</td>
<td>0.05±0.02</td>
<td>0.5±0.2</td>
<td>0.02±0.01</td>
</tr>
<tr>
<td>- Earth and sand</td>
<td>0.9±0.5</td>
<td>0.03±0.01</td>
<td>0.5±0.2</td>
<td>0.02±0.01</td>
</tr>
<tr>
<td>- Charcoal and ashes</td>
<td>0.6±0.2</td>
<td>0.02±0.01</td>
<td>0.4±0.2</td>
<td>0.01±0.01</td>
</tr>
<tr>
<td>- Carrion</td>
<td>0.1±0.1</td>
<td>0</td>
<td>0.6±0.2</td>
<td>0.02±0.01</td>
</tr>
<tr>
<td>- Straw</td>
<td>0.1±0.1</td>
<td>0</td>
<td>0.3±0.1</td>
<td>0.01±0.01</td>
</tr>
<tr>
<td>- Stones and gravels</td>
<td>0.4±0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.01±0.01</td>
<td>0.02±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>- Bones</td>
<td>0.2±0.1</td>
<td>0.01±0.01</td>
<td>0.1±0.03</td>
<td>0</td>
</tr>
<tr>
<td>- Dung</td>
<td>0</td>
<td>0</td>
<td>0.1±0.05</td>
<td>0</td>
</tr>
<tr>
<td>- Invertebrates</td>
<td>0.1±0.1</td>
<td>0</td>
<td>0.02±0.02</td>
<td>0</td>
</tr>
<tr>
<td>- Mushrooms</td>
<td>0.03±0.03</td>
<td>0</td>
<td>0.02±0.02</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Within each bite group, means with different letters are significantly different (P<0.05).

### Table 3
Size of acorn and grass bites (g); mean±S.E.

<table>
<thead>
<tr>
<th>Category</th>
<th>Fresh matter</th>
<th>Dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire acorn</td>
<td>5.7±0.2</td>
<td>–</td>
</tr>
<tr>
<td>Acorn kernel</td>
<td>4.4±0.2</td>
<td>2.5±0.1</td>
</tr>
<tr>
<td>Grass bite</td>
<td>1.4±0.1</td>
<td>0.26±0.02</td>
</tr>
</tbody>
</table>

### Table 4
Chemical composition of acorn and grass (g/100 g DM); mean±S.E.

<table>
<thead>
<tr>
<th>Category</th>
<th>Grass</th>
<th>Acorns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>24.05±1.52</td>
<td>58.05±1.28</td>
</tr>
<tr>
<td>Ash*</td>
<td>8.74±0.79</td>
<td>1.94±0.03</td>
</tr>
<tr>
<td>Crude protein*</td>
<td>15.73±0.73</td>
<td>4.71±0.21</td>
</tr>
<tr>
<td>Crude fibre*</td>
<td>21.28±0.78</td>
<td>2.83±0.09</td>
</tr>
<tr>
<td>Crude fat*</td>
<td>5.24±0.41</td>
<td>10.22±0.49</td>
</tr>
<tr>
<td>NFE*</td>
<td>64.83±4.56</td>
<td>65.46±0.62</td>
</tr>
</tbody>
</table>
throughout the day in periods of 15 min with or without drinking to ease the further study of drinking distribution throughout the day.

3.6. Statistical analyses

Data were analysed separately for two distinct montaneras and for both sexes. Results are expressed as mean±S.E. Effects of year on diet and behaviour were analysed in a one-way analysis of variance with montanera year as the main factor. A $p$-value of 0.05 was accepted as significant in all statistical tests. A Kolmogorov–Smirnov test was used to examine the normal distribution of variables.

4. Results

4.1. Climatic characteristics

Precipitations during September and October were enough for early grass growth in both montaneras. Later rains were enough to maintain grass growth and a similar grass production in the areas where pig grazed. However, the amount of fallen water and the number of rainy days was significantly affected by year (Table 1). Precipitations in M2 were limited and with greater intervals between episodes of rain. Consequently in M2 there was less available water to drink in puddles and streams during grazing.

4.2. Ingested resources and preferences

291,770 bites have been registered for the two montaneras. Their frequency distribution (Table 2) shows grass and acorns as the main resources with a mean, for both montaneras, of 56.5% and 43.3% of bites respectively. The frequency distribution of bites for both resources was the same for both montaneras (99.7±0.05% versus 99.7±0.7%). Fourteen other resources different from acorn and grass were registered but at a much lower frequency and only 9 resources at frequency $\geq 0.01\%$.

The percentage distribution for daily bites did not show any significant difference between montaneras, for either consumed acorns ($P=0.064$) or grass bites ($P=0.069$). However, daily number of eaten acorns was significantly higher in M1 ($P=0.031$). Although the number of grass bites was higher in M2, the difference was not significantly different.

The overall number of bites of other resources is similar in both montaneras but shows a high diversity and a very high coefficient of variation. These other resources were eaten in a similar low proportion between both montaneras and the different categories did not have a normal distribution. Roots (mainly of *Carlina racemosa*), earth and sand, inorganic rubbish, charcoal and ashes, stones and gravels bites (mainly rubble associated with very old ruins) were apparently consumed by more pigs during M1; whereas carrion, bushes (*L. stoechas, Cistus salvifolius, T. zygis* and *Carex* sp.) and berries (of *Rethama sphaerocarpa*) were apparently consumed by more pigs in M2. However these numbers are very small to make any valid comparison.

Differences between sexes were not statistically significant.

4.3. Size and composition of bites

The Iberian pig does not utilise the entire acorn because is very skilled at peeling the acorn and discarding

<table>
<thead>
<tr>
<th>Fresh matter</th>
<th>DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole acorn</td>
<td>M1 8.37±0.63$^a$</td>
</tr>
<tr>
<td>Acorn endocarp (E)</td>
<td>M1 6.4±0.48$^a$</td>
</tr>
<tr>
<td>Grass (G)</td>
<td>M1 2.04±0.21</td>
</tr>
<tr>
<td>Total intake (E+G)</td>
<td>M1 8.45±0.54</td>
</tr>
</tbody>
</table>

$^a$ Within each bite group, means with different letters are significantly different ($P<0.05$).

### Table 5
Statistical description of daily acorn and grass intake (kg); mean±S.E. and percent

<table>
<thead>
<tr>
<th></th>
<th>Fresh matter</th>
<th>DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole acorn</td>
<td>M1 8.37±0.63$^a$</td>
<td>M2 7.13±0.24$^b$</td>
</tr>
<tr>
<td>Acorn endocarp (E)</td>
<td>M1 6.4±0.48$^a$</td>
<td>M2 5.45±0.18$^b$</td>
</tr>
<tr>
<td>Grass (G)</td>
<td>M1 2.04±0.21</td>
<td>M2 2.67±0.22</td>
</tr>
<tr>
<td>Total intake (E+G)</td>
<td>M1 8.45±0.54</td>
<td>M2 8.12±0.32</td>
</tr>
</tbody>
</table>

$^a$ Within each bite group, means with different letters are significantly different ($P<0.05$).

### Table 6
Analysed composition of daily whole voluntary intake (g of DM and % of DM); mean±S.E.

<table>
<thead>
<tr>
<th></th>
<th>Weight (g)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M1</td>
<td>M2</td>
</tr>
<tr>
<td>Ash</td>
<td>103.37±6.45</td>
<td>102.96±4.47</td>
</tr>
<tr>
<td>Crude protein</td>
<td>230.26±14.6</td>
<td>222.95±8.88</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>182.97±11.68</td>
<td>192.17±9.79</td>
</tr>
<tr>
<td>Crude fat</td>
<td>390.63±28.16</td>
<td>341.59±11.24</td>
</tr>
<tr>
<td>Free-nitrogen extractives</td>
<td>2619.98±182.39</td>
<td>2341.78±77.93</td>
</tr>
</tbody>
</table>

$^a$ Within each group of nutritive components, means with different letters are significantly different ($P<0.05$).
the shell (Aparicio Macarro, 1988). So a bite of acorn corresponds to its endocarp or kernel. Table 3 shows mean size of acorn and grass bites. Other resources bite size or weight have been disregarded due to their low frequency and insignificant intake.

Chemical composition of acorn endocarp and grass is showed in Table 4. The acorn endocarp has a very low concentration of crude protein but a very high content of NFE and crude fat. Conversely, grass has a higher level of crude protein but a lower concentration of crude fat and a similar content of NFE.

4.4. Daily food intake

Daily acorn intake was significantly affected by the year (Table 5). The first year pigs ate slightly more acorns than the second year ones. However, there were no other significant effects of the year either on daily grass intake ($P=0.068$) or total daily DM food intake ($P=0.109$). However, distribution of daily total intake of fresh matter and DM of acorn and grass (Table 6) demonstrated significant differences between years with a higher percentage of acorn matter during M1 versus a higher percentage of grass matter during M2.

Assuming a constant composition for grass and acorn, the nutritive composition of voluntary grazing feed and daily intake did not differ significantly between both montaneras; statistically the main difference corresponds to crude fat ($P=0.06$). However the analysed composition differs significantly in percentage terms between both montaneras: percentage of ash, crude protein and crude fibre are higher in M2; while percentage of NFE and crude fat are higher in M1.

4.5. Drinking

Number of drinks and number of periods of 15 min with any drink (Table 7) were significantly affected by year; so, the highest number of drinks was registered during M1. Due to a lack of puddles and water in streams during M2, pigs had to return to the night enclosure to drink.

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinks</td>
<td>9.1±0.8 a</td>
</tr>
<tr>
<td>periods of 15 min with any drink</td>
<td>6.3±0.5 a</td>
</tr>
</tbody>
</table>

* Within each bite group, means with different letters are significantly different ($P<0.001$).

4.6. Grazing and activity time

Daily grazing and related activity time (Table 8) was significantly affected by the year with the first year pigs grazing for longer than the second year ones. Therefore pigs spent $>60\%$ of the observation period ($>54\%$ of the daylight hours) engaged in foraging activity.

All pigs, without exception, returned to the night paddock to rest inside the hoops as they finished their grazing day. All returns were before 18:30 pm, the latest one was 3 min before this time and it was during M1. The beginning hour of the final rest and the end of grazing day was significantly affected by the year with the first year pigs grazing until 508.2±15.6 min after 8:30 h versus 390.5±8.8 ($P<0.001$).

5. Discussion

The direct in situ observation method used, with continuous observation of grazing and monitoring individual feeding behaviour has permitted the recording of all consumed resources and the evaluation of the pig omnivorous diet. According to Forbes (1995) there is no substitute for this methodology in terms of learning about animal behaviour with certain types of behaviour not being amenable to quantification in any other way. However, this method suffers from two major drawbacks: firstly, it is very time-consuming, however this cost was taken on (940 h following pigs) because there was no previous study about behaviour during montanera; secondly, it does not provide information on the weight of food eaten. This latter obstacle has been resolved by simulation and weighing of grass bites and obtaining the mean weight of acorns.

Therefore, according to the predictions, pig diet is based upon acorn and grass, the most abundant resources in the area during the study season, showing a manifest stenophagy. Wild boar also bases its diet on the two or three most abundant and available feed resources Fournier-Chambrillon et al. (1993); and Sáenz De Buruaga (1995) found that acorns were 87.1% of diet DM for wild boar in Northern Spain.

Mean weights of different acorn components were similar to the reported ones by Fernández et al. (2004) in
roots (Abigar, 1993). Montanera grazing is a repeated ingestion of small quantities of food. However, in spite of altering the underlying level of feeding motivation due to the small quantities in indoor breeding conditions (Day et al., 1996), grazing pigs rise to a high intake levels along the whole day. Therefore, mean daily consumption of entire acorns is lower than the previous rough calculations of 8 to 10 kg traditionally proposed by several authors for Iberian pig (e.g. Ugarte and Velaz De Medrano, 1921; Laguna, 1998).

Pigs are also able to select plants or parts of plants so that the quality of the consumed herbage mass differs from the overall quality of the pasture (Gustafson and Stern, 2003). Grass bites were very light but pigs needed a lot of them as a source of protein to compensate for the low concentration of this nutrient in acorns. There are very few previous rough calculations for fresh grass daily consumption in montanera and those estimations are lower. López Bote et al. (2001) proposed 800–2000 g, Dobao et al. (1988) estimated 1000–1500 g and Aparicio Macarro (1988) proposed 3000 g of grass. Differences of grass and acorn consumptions with previous authors can be explained because these are based on estimations from acorn and grass composition and daily weight gain.

Other resources intake doesn’t differ between years and within years between pigs because this distribution of frequency is not normal. These resources confirm pig omnivorism, stenophagy and dietary opportunism.

*R. sphaerocarpa* legumes could be a protein resource, due to their high protein content; however these are difficult to access by montanera time because these are not yet on the ground. Although other authors found that feral pigs are fond of carrion (Hanson and Karstad, 1959; Nichols, 1962) and it could be another protein resource, this was not fully consumed, only partially bitten.

Conversely, inorganic rubbish and wood bites could be reflecting an exploratory motivation and an extreme curiosity, in accordance with Day et al. (1995) who found that visits to novel objects was an expression of intrinsic exploration as it was independent of feeding motivation.

Eagerness towards roots of thistles (*C. racemosa*) is surprising, especially as pigs were nose-ringed and this root is very fibrous. A previous study of wild boar also showed an important autumnal intake of other thistle roots (*Eryngium campestre*) (Abagar, 1993).

Charcoal and ashes were very scarce but pigs ate these avidly. Their interest could be related to mineral requirements as suggested Aparicio Macarro (1988) or could be a tasty food. Bites to pieces of bone and earth could have a similar explanation.

Several authors point out the low concentration of protein in acorns and the importance of grass as a source of protein (e.g. Aparicio Macarro, 1988; López-Bote, 1998; Nieto et al., 2002) and of (n-3) fatty acids, which may be important for the development of flavour characteristics in the products (Rey et al., 2006). Moreover, it has been reported that α-tocopherol concentration in muscular tissue of Iberian pigs is significantly higher if feeding is carried out in montanera than if it is done with formulated feeds containing a basal level of α-tocopheryl acetate (3 versus 2.2 µg α-tocopherol/g muscle). This is because of the high concentration of α-tocopherol in the grass (171 mg/kg DM) (Rey et al., 1997).

Considering voluntary daily pig routine observed in semi natural environment (Stolba and Wood-Gush, 1989) it is foreseeable to have controlled the whole voluntary grazing day without any disturbance by the sunset closing of the night paddock.

Pigs spend >54% of the daylight hours engaged in foraging activity, which is close to 52% of activity time foraging found by Stolba and Wood-Gush (1989) and also to >50% proposed by Aparicio Macarro (1988) for Iberian pigs during montanera.

In M2, many pigs came back to the night enclosure to drink because of a lack of water so their grazing activity time was lower and finished earlier. This is in accordance with Bigelow and Houp (1988) who found that 75% of the pigs’ daily water intake is closely associated with eating bouts and correlated to their feed consumption.

As a consequence of the differences in grazing time, pigs ate significantly more acorns during M1. Although pigs ate more grass during M2, this was not significantly different to M1. However, this extra grass consumption could be explained as an alternative source of water (this difference results in a mean of 473.05 ml of water by grass). This is in accordance with López Bote et al. (2001), who suggested that the water content of grass could reduce the number of visits to water troughs.

During M1, crude protein percentage was a bit lower and crude fat was a bit higher because of the significantly higher intake of acorns.

### 6. Conclusions

This study provides knowledge about the omnivorous diet of pigs in natural environments of dehesa without any supplementary food. Considering that the dehesa provides a rather homogeneous offer of natural resources (Rodriguez-Estévez et al., 2007) this study demonstrates...
that montanera fattening satisfies the pig to compose its diet and to reach physical satiety. This work encourages further studies that will help qualify the nature and structure of acorns and grasses that offer possible nutritional adjustments of dehesa for fattening pigs during autumn and winter and to study the underlying level of feeding motivation due to small quantities when pigs eat natural resources. The best way to simplify the observations could be to follow pigs less time but including hours around grazing end to estimate total grazing time.

Probably facilitating easy water availability is the most important handling factor to manage grazing behaviour, diet composition and further performance. So dehesa managers should consider to introduce some water trough in the pasture land in order to ensure better utilisation of the natural resources and grazing in the whole area. Also results prove that montanera fattening pigs need to consume grass and it could be sowed to facilitate forage availability.

The proportion of grass and acorns influences nutritional balance and fatty acid profile, which is the present official system (MAPA, 2007) to assess the absence of any supplementary feed during the montanera fattening of Iberian pigs. However, it has shown an individual and year variability in diet composition and these results can contribute to explain final fattening performance differences and meat quality.

Considering that acorn production has been quantified in 8–14 kg per tree (Rodríguez-Estévez et al., 2007) an Iberian pig should eat approximately the acorn production of 0.5–1 tree per day during montanera fattening. These results are useful to determine set stocking in order to guarantee the traditional finishing system without concentrates or any supplementary feed.

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