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Consumption of Acorns by Finishing Iberian Pigs and Their Function in the Conservation of the Dehesa Agroecosystem

Vicente Rodríguez-Estévez*, Manuel Sánchez-Rodríguez, Cristina Arce, Antón R. García, José M. Perea and A. Gustavo Gómez-Castro
Departamento de Producción Animal, Facultad de Veterinaria, University of Cordoba Spain

1. Introduction

The dehesa is an ancient agrosilvopastoral system created by farmers to raise livestock, mainly on private lands. This system is highly appreciated by society and enjoys legal protection of the authorities because it is rich in biodiversity, a home to critically endangered species (Iberian lynx, imperial eagle and black vulture); a significant carbon sink; ethnologically and anthropologically valuable (culture and traditions); and is known for its scenic value. The dehesa also underpins rural development and is valuable for, inter alia, ecotourism and rural tourism; hunting and shooting; fire prevention; wood and charcoal; and for fodder (grass and acorns). However, most of these values do not produce any benefit to farmers and they do not receive any kind of support from these contributions.

The dehesa is both a resilient and a fragile system; its resilience derives from the perseverance of its operators, and its fragility is its susceptibility to unfavourable economic factors that influence its profitability (Siebold, 2009).

Livestock grazing is an integral management component of a dehesa and undergirds the conservation function of the system. The livestock component, including cattle, accounts for the largest fraction of revenue from the dehesa. However, the Iberian pig is the most appreciated and highly priced livestock, because of its outstanding quality of cured products when finished on acorns in the dehesa.

Although farmers do not receive any support from society for the contribution of the dehesa to welfare of society and the environment, they still conserve, prune and reforest oaks to maintain fruit production to feed and fatten Iberian pigs during the *montanera* or pannage. The ability of the Iberian pig breed to feed on acorns is a key feature in maintaining the dehesa. Despite the pivotal role that the dehesa plays in biodiversity conservation and human welfare in the Iberian Peninsula, quantitative and qualitative information about the ecology and productivity of this Mediterranean agrosilvopastoral system is scarce. In the absence of documented evidence of the biological value and ecosystem services of the system, biodiversity and human livelihoods are threatened.

* Corresponding Author

This chapter synthesizes existing knowledge on (i) historical and ecological perspectives of the dehesa, and the factors affecting acorn production and composition; (ii) acorn as a feed for Iberian pig production and nutritional value of acorns and their effect as a fattening diet in the dehesa; and (iii) how the relationship between the Iberian pig and the dehesa contributes to maintenance of biodiversity in the dehesa and its profitability. This work is based on an extensive literature review of publications and the authors' on-going studies in the dehesa and the grazing behaviour and performance of the Iberian pig.

2. The dehesa

2.1 The origin, definition, and evolution of dehesa

Oak woodlands and savanna are an extensive forest type in Mediterranean climate regions of the world; known as hardwood rangelands in California, "dehesa" in Spain, and "montado" in Portugal (Standiford et al., 2003). Specifically the term "dehesa", with its many definitions, refers to an agroecosystem. The first definition focuses on the word´s etymology: "deffesa", a Latin word for defence, referring to an early system of grazing land reserved for cattle use (for the breeding, grazing and rest), a fenced plot of land protected from cultivation and complete deforestation. According to Coromines (1980), there is evidence of the use of the word "dehesa" since the Middle Age (924); previously, the visigothic laws used the term "pratum defensum" with the same meaning.

The Spanish Society for the Study of Pastures (S.E.E.P.) defines "dehesas" as surfaces with trees that are more or less dispersed and a well developed herbaceous stratum, the stratum of shrubs having been eliminated to a great extent; these have an agricultural (ploughed land in long term rotations) and stockbreeding origin; and their main use is for extensive or semi-extensive grazing, using grasses, browse pastures and fruits of trees (Ferrer et al., 1997). This is a landscape like savanna; however, dehesa is an agroecosystem mainly associated with trees of the genus *Quercus*. Costa et al. (2006) indicate that the evergreen oak (*Q. ilex rotundifolia*) is the priority specie in the 70.1% of the dehesa surface.

Palynological analysis of Neolitic sites evidenced the existence of this agroecosystem since 6000 years ago (López Sáez et al., 2007), when the Mediterranean forest was cleared to have grasslands while conserving the *Quercus* trees; mainly evergreen oak (*Q. ilex rotundifolia*) and cork oak (*Q. suber*). Besides, the distribution of evergreen oak (*Q. ilex*) forests have been severely impacted by human transformation in the Iberian Peninsula, and at the same time there has been a selection of trees looking for higher production of fruit, and bigger and sweeter acorns (Blanco et al., 1997). The historical expansion of the dehesa is linked with the Castilian Christian reconquest of the Iberian Peninsula from the Arabian and the subsequent repopulation and redistribution of land; and with the establishment of the long distance transhumance, where the dehesa area was the wintering pasture (from November to May).

Nowadays, the most widely accepted definition for dehesa is that of an agrosilvopastoral system developed on poor or non-agricultural land and aimed at extensive livestock raising (Olea and San Miguel-Ayanz, 2006). The characteristics of traditional dehesa uses in the Iberian Peninsula (southwestern Spain and southern Portugal) are (adapted from Carruthers, 1993):

- Natural reforestation and selection of trees for fruit production

- Regular pruning and diverse use of the tree layer (firewood, charcoal, fodder and acorns for human consumption and grazing animals)
- Mixed livestock of cattle, sheep, pigs, goats, etc. (mainly sheep from autumn to spring and finishing pigs during autumn and winter)
- Use of hardy and autochthonous breeds
- Low stocking densities (0.5–1 suckling ewe equivalent per ha)
- Shepherding and regular livestock movements (transhumance and trasterminance)
- Control of pasture productivity through directing livestock manure to selected places by nocturnal penning (called "majadeo" or "redileo")
- Extensive tillage in change with 3–20 years of fallow
- Numerous marginal uses (bee-keeping, hunting, edible wild plant and mushroom collecting, etc.)
- Employment of numerous specialized workers
- No use of externally produced fodder and energy

The traditional dehesa adopted a strategy of efficiency and diversification of structural components to take advantage of every natural resource (multiple, scarce and unevenly distributed in time and space) of its environment with a minimum input of energy and materials (Olea and San Miguel-Ayanz, 2006). Silviculture is not aimed at timber production but at increasing the crown cover per tree and at producing acorns (Olea and San Miguel-Ayanz, 2006), although there is no definitive evidence of successive better acorn masts after pruning (Rodríguez-Estévez et al., 2007a). On the other hand, in recent years, pruned biomass of browse and firewood have low value, and this wood´s only worth is to pay the woodcutters; however the pruning of adult trees is good to maintain the health of the trees and the forest mass when ill branches are cut. For the farming component, the major goal of land cultivation is preventing the shrub invasion of grasslands and supplying fodder and grain for livestock, harvesting being a secondary goal (Olea and San Miguel-Ayanz, 2006). Hence the current use and valuable production of the dehesa is mainly livestock breeding. Rodríguez-Estévez et al. (2007b) point out that cattle participate in the dehesa creation and are indispensable to its maintenance, while silviculture and agriculture are very secondary once a dehesa is kept in equilibrium with grazing. Due to that diversification and efficiency, the dehesa was also a very versatile system and was able to successfully satisfy human requirements and that has been the secret of its survival (Olea and San Miguel-Ayanz, 2006). However, from the last quarter of the twentieth century, its economy is totally dependent on livestock production and its associated subsidies.

Today, the dehesa is the most unique and representative agroecosystem of the Iberian Peninsula, currently consisting of more than four million hectares in the southwest (Fig. 1) (Olea and San Miguel-Ayanz, 2006), extending over Extremadura (1.25 million hectares), western Andalusia (0.7 million hectares), the south of Castilla-Leon and the west of Castilla la Mancha in Spain, as well as the Alentejo (0.8 million hectares) and the north of the Algarve in Portugal, where it is called "montado".

Most dehesas are divided into large estates (>100 ha) and are held in private ownership. Hence their conservation depends on good farming practices. The term dehesa has become internationalized and is being used in different languages. Furthermore, nowadays it is considered as an example of a stable and well managed agroecosystem from an ecological

point of view (Van Wieren, 1995). The dehesa has evolved over centuries into a sustainable agrosilvopastoral systems with conservation and human livelihood functions.

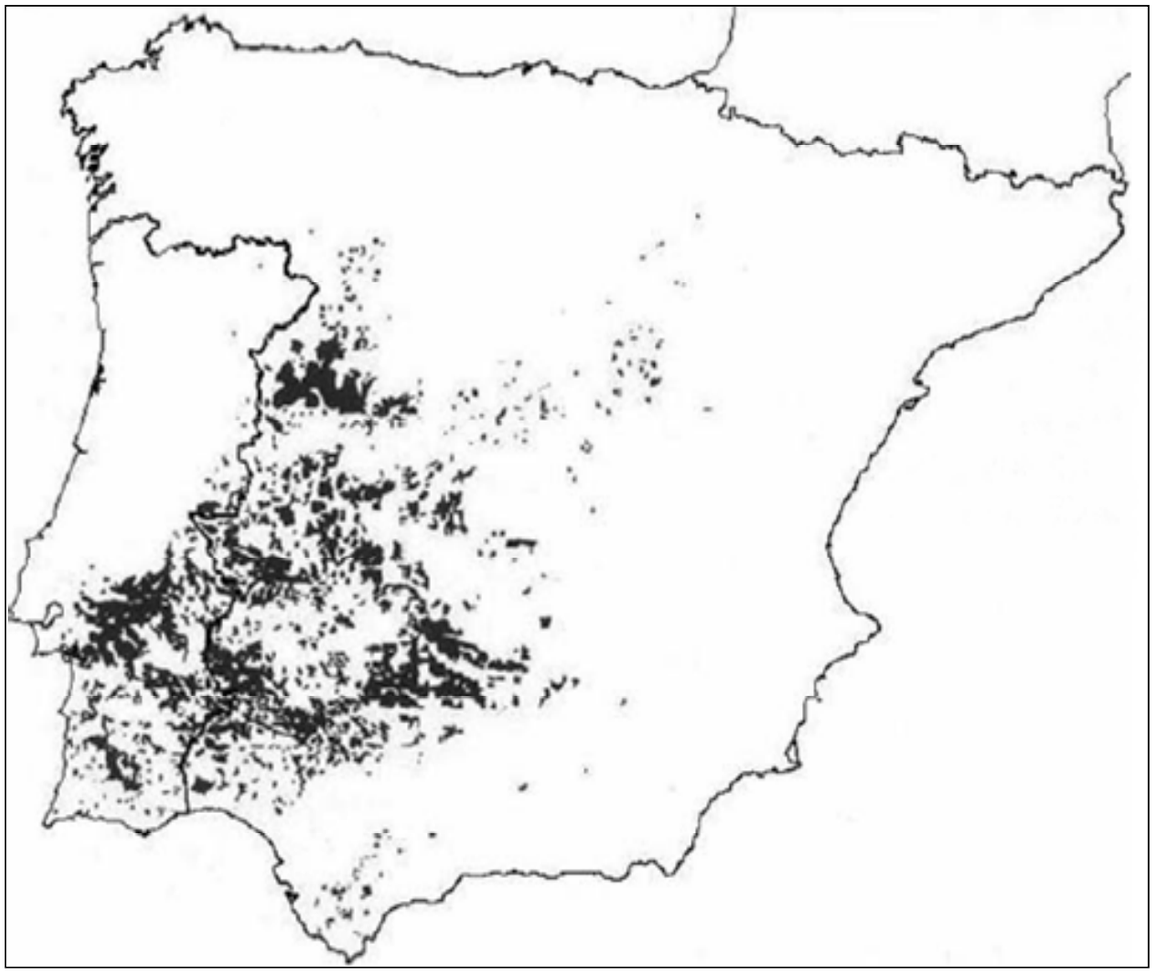

Fig. 1. Geographical distribution of the dehesa in the Iberian Peninsula.

2.2 The dehesa as a cleared forest

According to Rodríguez-Estévez (2011), the reason for conservation of the evergreen oak was its role as panacea or cultural tree due to its numerous uses: fuel (wood, coal and cinder), construction (beams and fencing), crafts, folk medicine, tanning, human food (acorns) and animal feed (acorns and tree fodder) and animal protection (shade and shelter). Besides, there are other values such as microclimate regulation and pumping of nutrients from the ground. All of them were possible reasons for conservation of *Quercus* trees when clearing the Mediterranean forest in the past centuries.

A dehesa should have a minimum number of trees, although the SEEP definition does not provide this specification (Ferrer et al., 2001). Different regulations have tried to establish this minimum from the 15th century (Vázquez et al., 2001) to now; for example: 10 trees per hectare (MAPA, 2007) and a surface of canopy projection between 5% and 75% (Presidencia,

2010). Viera Natividae (1950) proposes an ideal tree cover of 2/3 of the land for *Quercus suber*, while Montoya (1989) indicates a maximum of 1/3 for *Q. ilex*. These proportions match up with the number of good producer trees that are naturally present in the *Quercus* mass of the Mediterranean forest, and with the usual densities of the good pannage dehesas (Montoya and Mesón, 2004). Montero et al. (1998) show that the highest production of grass and acorns in the dehesas of *Quercus ilex* and *Q. suber* is reached when the tree density equivalent canopy cover of 30-50% is achieved.

Fig. 2. Aerial view of an area of dehesa (Summer 2011, Fuente Obejuna, Córdoba, Spain); at the bottom of the image is the Natural Park "Sierra de Hornachuelos", included in the Biosphere Reserve "Dehesas de Sierra Morena".

Traditionally, the ideal denseness for dehesa is 45 adult trees/ha (Rupérez Cuéllar, 1957). Several studies have estimated the number of adult trees for dehesas of *Q. Ilex* to be in the range of 20-50 trees/ha (Cañellas et al., 2007; Escribano and Pulido, 1998; Espejo Gutiérrez de Tena et al., 2006; Gea-Izquierdo et al., 2006; Vázquez et al., 1999) (Fig. 2). However, Plieninger et al. (2003) found a lower density in cultivated dehesas (18.9 trees/ha) than in grazed areas (38.6 trees/ha) and those invaded by brushy ones (38.6 trees/ha). The same authors also gave a mean of 16.6 trees/ha for aged or diminished dehesas.

The decline in numbers of *Quercus* spp. (referred to as the "seca" syndrome) is due to fungi and several defoliators, which is serious for *Q. ilex* and *Q. suber*, causing an important problem of mortality (Fig. 3). In some areas, average annual mortality ranges from 1.5 to 3% (Montoya and Mesón, 2004). This is considered to be the main problem of the dehesa, due to currently low or no natural regeneration (Olea and San Miguel-Ayanz, 2006). Intensification of land use through the current increase in livestock stocking rates for profit maximization has led to over-exploitation of forage, leading to suppression of oak regeneration under these circumstances.

The European Union Common Agricultural Policy subsidy for extensive livestock production compensated farmers for negative livestock value. However, authorities make a serious mistake when they consider 170 kg of nitrogen per hectare and year as the maximum limit of excretion for extensive exploitation, as it is established by the European Nitrates Directive (Council of the European Communities, 1991). Pulido García (2002) reported that the average stocking rate increased by 84% between 1986 and 2000 in the Extremadura region. The average stocking rate of 0.46 LU/ha is much lower than the maximum stocking rate of 1.4 LU/ha established by the EU threshold of extensification (Council of the European Communities, 1999). However, Olea and San Miguel-Ayanz (2006) suggest that the sustainable stocking rate of the dehesa is 0.2 – 0.4 LU/ha.

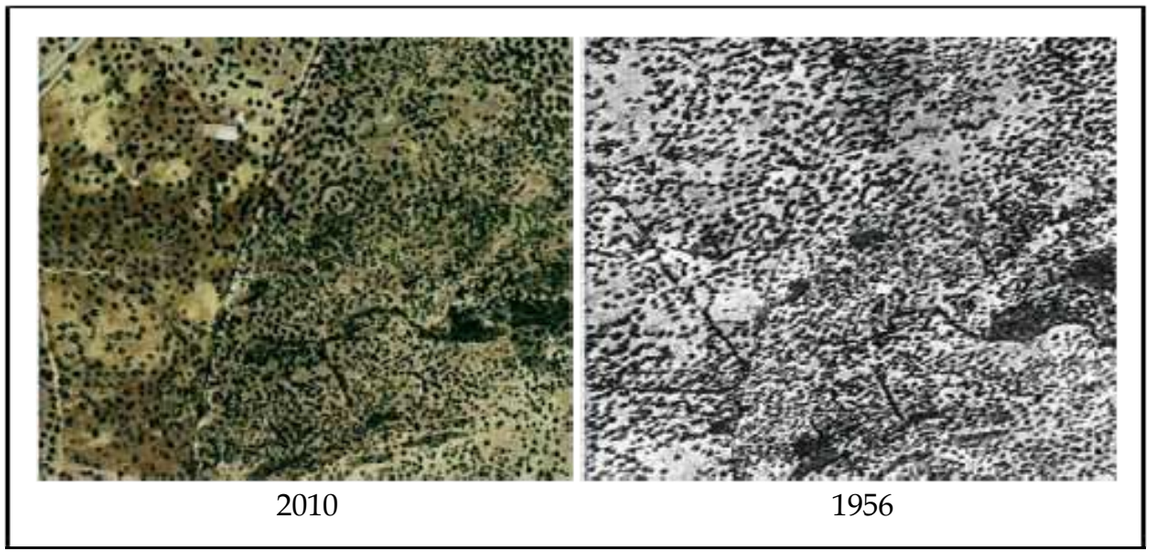

Fig. 3. Aerial view of an area of dehesa (Cañada del Gamo, Fuente Obejuna, Córdoba, Spain).

2.3 The ecological values of the dehesa

The typical environment of the dehesa is marked by two fundamental features: the Mediterranean character of the climate (dry summers and somewhat cold winters) and the low fertility of the soil (particularly P and Ca), making arable farming unsustainable and unprofitable (Olea and San Miguel-Ayanz, 2006). Within this difficult environment, the dehesa has arisen as the only possible form of rational, productive and sustainable land usage. The dehesa is a highly productive ecosystem and has been qualified as "natural habitat" to be preserved, within the European Union Habitats Directive, because of its high biodiversity (Council of the European Communities, 1992). This directive considers it as a "natural habitat type of community interest" included in the "natural and semi-natural grassland formations", where it is called "sclerophyllous grazed forests (dehesas) with *Quercus suber* and/or *Q. ilex*"; besides, it advises the designation of special areas for dehesa conservation (Fig. 4).

The dehesa harbours wildlife that is typical of the Mediterranean forests, but it is also enriched with representatives from other habitats, including steppes and agricultural environments. Dehesas are widely recognised as being of exceptional conservation value

(Baldock et al., 1993; Telleria and Santos, 1995; Díaz et al., 1997; Rodríguez-Estévez et al., 2010a). Thirty percent of the vascular plant species of the Iberian Peninsula are found in the dehesas (Pineda and Montalvo 1995). Marañón (1985) discovered 135 species on a 0.1 ha plot in a dehesa in Andalusia and considered the dehesa one of the vegetation types with the highest diversity in the world at this scale, having the highest one between the Mediterranean ecosystems (Fig. 5). Dehesas are the habitat of several species which are rare or globally threatened including black vultures (*Aegipius monachus*), Spanish imperial eagles (*Aquila adalberti*) and Iberian lynx (*Lynx pardina*); besides 6 to 7 million woodpigeons (*Columba palumbus*), 60000 to 70000 common cranes (*Grus grus*), both of them with diets based on acorns, and a large number of passerines depend on the dehesas as their winter habitat (Tellería, 1988).

Cork tree (*Quercus suber*) at the bottom and wild olive tree (*Olea europaea sylvestris*) on the right of the image.

Evergreen oaks (*Quercus ilex rotundifolia*)

Fig. 4. Iberian growers foraging in a dehesa during spring in dehesa San Francisco (Fundación Monte Mediterráneo, Santa Olalla del Cala, Huelva, Spain) organic farm in the Natural Park "Sierra de Aracena y Picos de Aroche", included in the Biosphere Reserve "Dehesas de Sierra Morena".

Although the dehesa productivity is low when compared with modern intensive agricultural production systems, its model inspires agri-environmental policies to maintain and promote farming practices compatible with nature conservation and biodiversity (Rodríguez-Estévez et al., 2010a). In this sense, Gonzalez and San Miguel (2004) indicate

that the meadow is a paradigm of balance and interdependence between production and nature conservation, where its high environmental values are a result of its extensive management, balanced and efficient, which can be considered a powerful conservation tool.

Fig. 5. Pregnant Iberian sows grazing in a dehesa during spring (Turcañada S.L., Casa Grande, Fuente Obejuna, Córdoba, Spain).

3. Acorn production in the dehesa

The productivity of acorns (the most important food resource for autumn and winter) is 10 times higher in a managed dehesa compared to a dense *Quercus ilex* forest (Pulido 1999). It is estimated that *Q. ilex* does not give an optimal yield of acorns until it is 20-25 years old. Rodríguez-Estévez et al. (2007a) estimated a mean acorn yield of 300 to 700 kg/ha; with yields of 8-14 kg/tree for *Q. ilex*, 5-10 kg/tree for *Q. suber* and 1-11 kg/tree for *Q. faginea* (Table 1). Acorn yields are extremely variable, both between and within years and individual trees. Rodríguez-Estévez et al. (2007a) also assessed the effect of density of adult trees (optimum estimated in 20-50 trees/ha), masting phenomenon (with cycles of 2-5.5 years and asynchrony between trees), individual characteristics of trees (genetic potential, age, canopy surface, etc.), tree mass handling (with favourable effect of tilling, moderate pruning and sustainable grazing), meteorological conditions (mainly drought and meteorology during flowering) and sanitary status (*Lymantria, Tortrix, Curculio, Cydia, Balaninus* and *Brenneria*) on acorn production. They concluded that tree density was the factor with greatest effect on the acorn production per hectare and tree in any dehesa.

Quercus spp.	**kg acorn/tree**	**g acorn/m² canopy**	**References**
Q. faginea	1 to 11	-	Medina Blanco, 1956
Q. canariensis	0.8 to 3.7	11.6 a 48	Martín Vicente et al., 1998
Q. suber	4.5 to 11	-	Medina Blanco, 1956
Q. suber	5 to 10	-	Montoya, 1988
Q. suber	0.6 to 16.9	19.5 a 171.1	Martín Vicente et al., 1998
Q. ilex	16.74	-	Medina Blanco, 1956
Q. ilex	4.4 to 20	-	Rupérez Cuéllar, 1957
Q. ilex	7 to 8	-	López et al., 1984
Q. ilex	10 to 15	-	Montoya, 1989
Q. ilex	14.8	-	Cabeza de Vaca et al., 1992
Q. ilex	10 to 14	-	Espárrago et al., 1992
Q. ilex	12 to 14	-	Espárrago et al., 1993
Q. ilex	14.8	-	Benito et al., 1997
Q. ilex	7.1 to 25.3	115.8 a 285.8	Martín Vicente et al., 1998
Q. ilex	18	-	Porras Tejeiro, 1998
Q. ilex	4.3 to 11.9	-	Vázquez et al., 1999
Q. ilex	14.1 to 5.2	-	Vázquez et al.,2000b
Q. ilex	4.5 to 8.4	-	Vázquez et al., 2002
Q. ilex	5.7 a 13.2	-	García et al., 2003
Q. ilex	12 a 65	-	López-Carrasco et al., 2005
Q. ilex	15-21	100	Gea-Izquierdo et al., 2006
Q. ilex	10.3 a 45.6	-	Moreno Marcos et al., 2007
Q. ilex	9.7	-	Hernández Díaz-Ambrona et al., 2007
Q. ilex	-	59.6 a 278	Lossaint and Rapp, 1971
Q. ilex	-	14	Verdú et al., 1980
Q. ilex	-	189.4	Gómez Gutierrez et al., 1981
Q. ilex	-	120.4	Escudero et al., 1985
Q. ilex	-	75.2	Leonardi et al., 1992
Q. ilex	-	25.9	Bellot et al., 1992
Q. ilex	-	1.0 a 237.4	Cañellas et al., 2007
Q. pyrenaica	-	48.6	Escudero et al., 1985

Table 1. Acorn production of ***Quercus*** spp in dehesas and Mediterranean forests (Resource: Rodríguez-Estévez et al., 2007a).

There is a high intraspecific variability in acorn traits and they account for 62% of the variance of the biomass of acorns (Leiva and Fernández-Ales, 1998). Besides, in most areas, there has been an historical selection favouring trees with larger acorns. Acorn weight, size and shape present a lot of variability between species, individuals and areas. From a sample of 2000 acorns from 100 evergreen oaks (20 acorns per tree) of a traditional dehesa, the average weight of an acorn was 5.7±0.2 g, with averages of 4.4±0.2 g and 2.5±0.1 g of kernel fresh and dry matter (DM), respectively (Rodríguez-Estévez et al., 2009a) (Fig. 6).

Fig. 6. Acorns of evergreen oaks (***Quercus ilex rotundifolia***) found under 12 different close trees in a dehesa (the coin is an Euro).

Chemical contents of acorn kernel	**Nutritive value (g 100g^{-1} DM) (mean±S.E)**	
	Grass	**Acorns**(1)
Dry matter (DM)	24.05±1.52	58.05±1.28
Ash*	8.74±0.79	1.94±0.03
Crude protein*	15.73±0.73	4.71±0.21
Crude fibre*	21.28±0.78	2.83±0.09
Crude fat*	5.24±0.41	10.22±0.49
NFE*	64.83±4.56	65.46±0.62
Metabolic energy (MJ/kg DM)(2)	10.27	17.6

Table 2. Nutrient composition *(g/100 g DM) of acorn kernel and grass in the dehesa and Mediterranean forest; (Rodríguez-Estévez et al., 2009a). (1) Acorn kernel makes on average 77% of the whole fruit. (2) From García-Valverde et al. (2007).

Acorn kernel composition (Table 2) is variable and is influenced by its own maturation process and external agents (humidity, parasites, etc.) (Rodríguez-Estévez et al., 2008, 2009b). In contrast, shell and cotyledon proportions show higher homogeneity. Shell composition has a very high level of tannins and lignin, which affects its digestibility. Kernel has a very high level of glucids (80% of DM) and lipids (5-10% of DM), with oleic acid content upper 60%; however, protein level is very low (4-6% of DM) (Rodríguez-Estévez et al., 2008). Many wild and domestic species eat acorns; however, in the dehesa, acorns are used to feed fattening Iberian pigs because this breed is the single one capable of peeling them and because it raises the highest commercial value. On the other hand, the autumn production of grass has been estimated at 200–500 kg DM per hectare of dehesa (Medina Blanco, 1956; Escribano and Pulido, 1998).

4. The Iberian pig

The term Iberian pig refers to a racial group of native pigs from the Iberian Peninsula, which originated from *Sus mediterraneus* in ancient times (Aparicio, 1960; Dieguez, 1992). It is characterized by its rusticity and adaption to Mediterranean weather and environmental conditions, and fat producing ability with a high intramuscular fat content (Aparicio, 1960). A great amount of genetic heterogeneity exists, with black, red, blond and spotted varieties (Aparicio, 1960), the black and the red being the most abundant, and with or without hair. The popular name "pata negra" comes from their very narrow and short extremities, with pigmented hooves of uniform black colour. At the end of the finishing phase (140-160 kg) called “montanera” (meaning pannage) they can reach 60% carcass fat, 15 cm backfat thickness and 10-13% intramuscular fat content (López-Bote, 1998).

4.1 The traditional husbandry and breeding system of Iberian pig

The traditional husbandry and breeding system of Iberian pigs was described 2000 years ago by Columela, the Hispano-Roman writer. The Iberian pig has been raised for centuries to produce meat for dry-cured products (hams, shoulders and loins are the most valued). This carries on being the main objective of the production system. Besides, nowadays the quality of the meat products is emphasized; mainly due to its very specific properties and healthy mono-unsaturated fats with a high content of oleic acid (around 55%) from acorn diet and a very low concentration of linoleic and palmitic acids (around 8 and 20% respectively) (Flores et al., 1988). Currently, the Iberian pig production is restructuring, after a great increase of census during the last decade when it reached nearly half million of reproductive sows.

Consequently, there is a new market for fresh meat from intensive farming imitating the acorn diet fatty acid profile, exploiting the image of traditional products and consumers lack of information and trying to avoid official control based on the fatty acid profile (López-Vidal et al., 2008; Arce et al., 2009).

The whole traditional productive cycle of the Iberian pigs was organized to get them physiologically capable of foraging acorns during their finishing phase (montanera). An important aspect of their traditional handling is a long period of growing (or pre-fattening) and feed rationing, with diet based on natural resources (according to the availability of each dehesa land): spring grasses, stubble in summer, agriculture by-products, etc.; in order to take advantage of the pig compensatory growth (Rodríguez-Estévez et al., 2011).

Traditionally, farrowing occurred twice throughout the year, usually piglets born in December-January and June-July (one flock of sows with two batches per year), and the animals were weaned when over 1.5-2 months of age. The range of ages at the initial time of their montanera was therefore very wide (from 21-22 to 15-16 respectively), slaughtering the oldest pigs at almost 2 years old.

Nowadays, the batch for montanera finishing is usually the youngest one and it is pure Iberian breed; while piglets born in December-January are Duroc-Jersey crossbred intensively and fed with formulated compound feed. On the other hand, the montanera finishing system has its own legal regulation (MAPA, 2007), and it does not allow to begin finishing at an age lower than 10 months and limits the beginning weight from 80.5 to 115 kg; besides, it establishes that pigs should gain a minimum of 46 kg (4 *arrobas*; 1 *arroba* is a Spanish measure equivalent to 11.5 kg) grazing natural resources (mainly acorns and grass) during a minimum of 2 months.

Fig. 7. Iberian growers foraging the remains of acorns in a dehesa at the end of winter, which will be slaughtered after their second *montanera*, around 10 months later (dehesa Navahonda Baja, Natural Park "Sierra Norte de Sevilla", included in the Biosphere Reserve "Dehesas de Sierra Morena").

Pigs are slaughtered at high liveweights (14-16 *arrobas*, equivalent to 161-184 kg) because quality characteristics of the cured products require an extremely high carcass fat content and meat with high intramuscular fat content.

4.2 Acorn consumption by the Iberian pig

The legal requirements of Iberian pig meat and cured products (MAPA, 2007) does not allow offering pigs any supplementary feed, salt or mineral supplements during montanera;

hence, pigs are entirely dependent on natural resources during this finishing period, of at least 2 months. Studies, based on direct and continuous *in situ* observations of ingestive bites taken by continuously monitored pigs (during 10 uninterrupted hours per day of observation), show that the Iberian pig montanera diet is based on acorns and grass with 56.5 and 43.3% of grazing bites respectively; while only other nine resources (berries, bushes, roots, carrion, straw, etc.) were consumed at a frequency ≥0.01% (Rodríguez-Estévez et al., 2009a). This means a daily intake of 1251 to 1469 acorns or 7.13 to 8.37 kg of whole acorn and 2 to 2.7 kg of grass, during 6.1 to 7.1 foraging hours (Fig. 8).

Fig. 8. Iberian fatteners foraging acorns in a dehesa during montanera (from November to February) under the control and inspection of the Denomination of Origin "Los Pedroches" (Turcañada S.L., dehesa Casa Alta, Fuente Obejuna, Córdoba, Spain).

Iberian pigs peel acorns and split their shells due to the high content of tannins in shells; notably, this is the unique breed and domestic animal known to have this skill. However, during peeling there is an amount of kernel wasted per acorn (18.9±1.2 percent) and it presents a high degree of variation influenced by differences in the morphology and size of the acorns (Rodríguez-Estévez et al., 2009c). As a result of this, a positive correlation has been observed between the weight of the waste kernel and the weight of the whole acorn, as well as the diameter (Rodríguez-Estévez et al., 2009b). This could explain why the Iberian pigs deliberately select certain oak trees (eating at least 40 acorns per visit), while avoiding others (eating less than 10 acorns per visit) in spite of large numbers of acorns under their canopies (Rodríguez-Estévez et al., 2009c). Differences observed between the sought out and rejected acorns at the start and end of the montanera season are too large to be only a matter of chance, suggesting that Iberian pigs must form associations between variables when choosing to eat or reject the acorns from a specific tree. Pigs tend to select heavier acorns at the start of the montanera season, while at the end their selection is based more on the composition of the acorns. So, Rodríguez-Estévez et al. (2009c) observed that acorns with

mean weights of 5.73±0.37, 6.93±0.28 g were rejected and sought after, respectively, at the montanera start (November), and those weighing 3.18±0.2 and 3.44±0.11 g were rejected and sought out, respectively, at the end (February).

Fig. 9. Iberian fatteners foraging acorns in a dehesa in winter, close to their slaughtering (dehesa Navahonda Baja, Natural Park "Sierra Norte de Sevilla", included in the Biosphere Reserve "Dehesas de Sierra Morena").

The foraging and grouping behaviour of these pigs entails a balance between competition for resources and space (under tree canopies to eat acorns) and cooperation to look for the best patches (oak masts) with the heaviest and healthiest acorns. This behaviour has been termed as "Chase Optimal Foraging" (Rodríguez-Estévez et al., 2010b). Pigs walk a daily distance of 3.9±0.18 km to visit 96±3.7 trees in order to get a mean intake of 56.4±2.34 MJ of metabolic energy (ME) provided by grass and acorns (Table 3) (Rodríguez-Estévez et al., 2010c). With that intake the average daily weight gain of Iberian pigs has been found to be 0.79±0.03 kg during montanera fattening period. So, the corresponding food conversion rate, expressed in terms of whole acorns required to achieve the reported growth rate, taking into account the contribution of grass, is 10.5±0.75 (Rodríguez-Estévez et al., 2010c).

	Wet basis (kg)	Dry matter (kg)	Metabolic energy (MJ)
Acorn kernel	4.9±0.22	2.9±0.13	51.3±2.32
Grass	2.7±0.23	0.5±0.04	5.1±0.43
Total	7.6±0.31	3.4±0.14	56.4±2.34
Percent from kernel	66.9±2.19	85.1±1.32	90.4±0.93
Percent from grass	33.1±2.19	14.9±1.32	9.6±0.93

Table 3. Daily ingestion of acorn kernels and grass by fattening Iberian pigs grazing in the dehesa over the montanera season, mean±S.E. (N=60) (Rodríguez-Estévez et al., 2010c).

5. The Iberian pig and the dehesa conservation

In a past, there were similar pig fattening systems to the Iberian pig one in other European countries (Fig. 10). For example, in Great Britain, the Common of Mast was the right to turn out pigs during a season known as pannage, and it has survived in the New Forest; but finishing only 500-600 pigs per year. However, in other countries, the pig presence and its grazing and rooting habits became considered dangerous to the forests. Hence, the Iberian one is the only pig breed known which contributes to conservation of an ecosystem, considered a sustained production and a model for organic farming (freedom, welfare, and grazing diet without any chemical supplement). A very low stocking rate and a well conserved dehesa are necessary conditions to finish Iberian pigs grazing acorns and grass. These are the reasons because its contribution to conserve natural areas and to rural development is recognized by the Spanish authorities (MAPA, 2001 and 2007).

Fig. 10. Calendar page for November of "Les Trés Riches Heures du Duc de Berry" (France, 1410-1416).

Besides 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). Furthermore, the montanera finishing system is of a great interest

due to the differentiating characteristics that it provides to the carcasses and the products derived from them (e.g. healthy fatty acid profile). As a consequence, the meat of Iberian pigs is in great demand; and pigs, fattened under the traditional system, have been sold at prices up to 160% higher than conventionally raised animals, and dry cured hams sold between 350 and 500% higher in a recent past (FAO, 2007). Indeed, the main constraint for further increasing the output of these products is not lack of demand, but the limited range of the breed's traditional habitat. Besides, when fattening pigs in the dehesa, acorns are the most limiting resource during the montanera, because unlike grass, their supply is not continually renewed during the montanera season (Rodríguez-Estévez et al., 2010c).

To protect the system (the very effective couple Iberian pig and dehesa) and consumers from fraud, the Spanish authorities established the minimum standards to market Iberian pork and cured products (MAPA, 2001 and 2007). However, these standards have not been enough and have contributed to consumer confusion, while having favoured intensive production and marketing of cross breed Iberian pigs (Rodríguez-Estévez et al., 2009d).

According to the legal requirements of the current quality standard for the Iberian pig (MAPA, 2007), they need to be able to reach the slaughter weight (≥161 kg) only with natural resources consumed during grazing. To know the high food conversion rate of finishing Iberian pigs in the dehesa (10.5±0.75 kg of whole acorns to gain 1 kg, besides the contribution of grass) is the key for establishing their stocking rate in the montanera season (Rodríguez-Estévez et al., 2010c). Bearing in mind that an adult evergreen oak (*Q. ilex rotundifolia*) produces an average of 11 kg of acorns (Rodríguez-Estévez et al., 2007a), it could be assumed that a grazing Iberian pig requires the total annual production of acorns of an adult evergreen oak to obtain 1 kg weight gain (Rodríguez-Estévez et al., 2010c). So, stocking rate could be estimated dividing the number of adult oaks of a dehesa by the expected weight gain; a minimum of 46 kg according to quality standards (MAPA, 2007). Furthermore, having in mind the fact that Iberian pigs selectively feed on acorns with preferred traits (Rodríguez-Estévez et al., 2009c), the previous quotient should be considered a minimum to guarantie finishing only based on acorns and grass.

Quality standards demand a stocking rate <2 pigs/ha of dehesa, considering a minimum density of 10 trees/ha (MAPA, 2007). However, an average figure of 35 adult evergreen oaks/ha of dehesa has been reported (see Rodríguez-Estévez et al., 2007a). Accordingly, the stocking rate should be <1 pig/ha of dehesa so that the minimum standard of 46 kg weight gain, based only on natural grazing, can be achieved under sustainable conditions (Rodríguez-Estévez et al., 2010c).

Pigs should be as old as possible and adapted to grazing to make the best use of natural resources (mainly the limited acorn mast) while foraging during the montanera. The mean average daily gain for those pigs is 0.76±0.01 kg/day, and it is very much influenced by the age (Rodríguez-Estévez et al., 2011), due to a compensatory growth. To raise these pigs (older than a year and adapted) the best system is the traditional extensive one, based on a grazing diet. Hence, to produce profitable Iberian pigs finished on acorns is necessary to have well conserved dehesa lands (in terms of a high adult tree density and good pasture) to graze before and during the montanera season; all this implies expenses for: clearing brushes (mainly *Cistus* sp.), pruning, reforestation and fencing (to contain wild boars from the forests and, sometimes, to keep cattle out of wooded lots) (Fig. 11).

Fig. 11. Iberian growers grazing in a reforested dehesa at the end of spring (Natural Park "Sierra Norte de Sevilla", included in the Biosphere Reserve "Dehesas de Sierra Morena"). The perimeter fence and a firebreak are in the first line of the picture.

6. The protection of the traditional Iberian pig production

It is necessary a very clear and strict differentiation of Iberian pig production systems, without the current euphemistic official quality denominations (MAPA, 2007); for example, the two conditions to label a product as from "cerdo de campo", meaning "country pig", are >0.066 ha and ≥100 m between feeder and drinking trough, which is ridiculous. According to MARM (2010), 81.5% of slaughtered pigs in 2009 were reared in intensive farms, very far from the image that consumers have of Iberian pigs.

The establishment of more stringent standards, the requirement for more accurate controls to avoid frauds (for example: infrared spectroscopy; Arce et al., 2009) and a greater consumer information are keys to protect the traditional Iberian pig farms; because to maintain the montanera finishing system it is essential to conserve the dehesa agroecosystem and its profitability. In this sense, it has been proposed to establish stocking rates on the base of adult oaks density (a mean of 46 trees/pig), very easily calculated with the use of geographic information system (GIS) (Rodríguez-Estévez et al., 2010c).

Besides, the extra cost of an Iberian pig finished on acorns is estimated in more than 175 €/pig (1.1 €/kg live weight) to pay growing feed, labour (swineherd), pannage and financial cost. In other words, while the pork market does not pay this extra cost it will not be worth the traditional finishing system; because, currently it is more profitable to fatten pigs on feed using the good image of the Iberian breed (associated to the tradition and the dehesa) to sell these.

7. Conclusions

The dehesa is both a resilient and a fragile system created by farmers to raise livestock. This system is highly appreciated by society and its potential future support is mainly based on its ecological values. The continued supply of public values from private woodlands depends on their economic value and the opportunity costs of competing land uses. The last decade, its profitability has depended on its acorn production as a feed for fattening Iberian pigs. As pigs need a very high amount of acorns for finishing these require very well conserved dehesas (with optimal density of adult oaks).

The couple Iberian pig and dehesa has proved to be very effective; so much the Iberian pig is called the dehesa jewel, but the first needs this agroecosystem to reach its highest quality properties (organoleptic and nutritional ones); and the second needs a clear commercial differentiation for Iberian pork and cured products in order to receive a high price to maintain and conserve the dehesa. Hence, the Spanish authorities should be responsible for protecting this traditional system from fraud and unfair competition. In this way, farmers economy could be enough to conserve this unique ecosystem and its values for the whole society.

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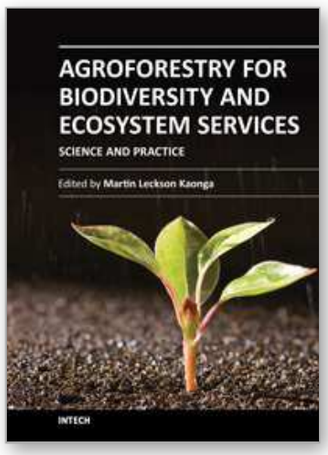

Agroforestry for Biodiversity and Ecosystem Services - Science and Practice

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Agroforestry has great potential for reducing deforestation and forest degradation, providing rural livelihoods and habitats for species outside formally protected land, and alleviating resource-use pressure on conservation areas. However, widespread adoption of agroforestry innovations is still constrained by a myriad of factors including design features of candidate agroforestry innovations, perceived needs, policies, availability and distribution of factors of production, and perception of risks. Understanding the science, and factors that regulate the adoption, of agroforestry and how they impact the implementation of agroforestry is vitally important. Agroforestry for Biodiversity and Ecosystem Services: Science and Practice examines design features and management practices of some agroforestry practices and their impact on biodiversity and the ecosystem services it delivers. It also identifies policy issues for facilitating adoption of desirable agroforestry practices and gradual diminution of undesirable policies.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
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Phone: +86-21-62489820
Fax: +86-21-62489821

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