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Abstract. The Mediterranean pig production systems which enhances the value of endogenous resources and ecosystems are increasingly appreciated by the society, due to the beneficial role they play in the environment and the lives of animals (ethical quality), and to the associated nutritional and organoleptic quality. The type of breed (local Mediterranean genotypes), age and weight at slaughter, the climatic conditions, the use of regional raw materials (acorns, oaks, chestnuts, grass and agricultural by-products) and the exercise that the animals do during grazing, are the main differentiating factors of meat quality of Mediterranean pigs. In general the pigs destined for the Mediterranean high-quality products (PDO, PGI) are slaughtered at weights well above the age of sexual maturity (120-160 kg BW), when muscle growth has stabilized and at the expense of greater capacity of deposition and infiltration of intramuscular fat (+60% monounsaturated), an essential condition in order to develop the organoleptic characteristics highly valued in the market by the great appreciators. In these production systems, swine productivity and quality of final products depend on the interaction between genotype, environment, proper planning and implementation of animal husbandry on the farm: nutritional management, acclimatization and rearing conditions, optimization of reproductive techniques, health standards and levels of animal welfare, contribute to a greater extent to loss or gains of productivity and quality. Although they use production systems that are very close to natural methods, these holdings may incorporate some advanced technologies for management in a way to permit optimization of the quality and the economy of Mediterranean pig meat chain and also benefit the environmental balance of resources and landscape.

Keywords. Animal management – Production system – Performances – Quality.

Systèmes de production et conduite durable du porc dans la région méditerranéenne

Résumé. *Les systèmes méditerranéens de production porcine qui permettent d'améliorer la valeur des ressources endogènes et des écosystèmes sont de plus en plus appréciés par la société, en raison du rôle bénéfique qu'ils jouent pour l'environnement et la vie des animaux (la qualité éthique), ainsi que de la qualité nutritionnelle et organoleptique des produits. Le type de race (locales méditerranéennes), l'âge et le poids d'abattage, les conditions climatiques, l'utilisation de matières premières régionales (glands, châtaignes, herbe et sous-produits agricoles) et l'exercice que font les animaux au cours du pâturage, sont les principaux facteurs de différenciation de la qualité de la viande des porcs méditerranéens. En général, les porcs destinés aux produits de haute qualité (AOP, IGP) sont abattus à des poids bien supérieurs à l'âge de la maturité sexuelle (120-160 kg de poids corporel), lorsque la croissance musculaire est déjà stabilisée au détriment d'une plus grande capacité de dépôt et d'infiltration de la graisse intramusculaire (+60% de gras mono-insaturé), une condition essentielle pour le développement des caractéristiques organoleptiques très appréciées sur le marché par les grands connaisseurs. Dans ces systèmes de production méditerranéens, la productivité et la qualité des produits dépendent d'un grand nombre d'effets génétiques et du milieu et de l'interaction entre les deux, donc une bonne planification ainsi que le développement de bonnes techniques d'élevage sont essentiels aux différents niveaux de conduite des animaux: nutritionnelle, acclimatation d'élevage, reproduction, sanitaire, permettant de hauts niveaux de bien-être animal. Bien que ces systèmes de production soient proches des méthodes naturelles, les exploitations peuvent intégrer des technologies de pointe visant à l'optimisation de la qualité, l'économie des filières et l'équilibre des ressources naturelles et des paysages.*

Mots-clés. *Système de production – Techniques d'élevage – Performances – Qualité.*

I – Introduction

For many centuries in the Mediterranean region, the swine production systems and the husbandry of pigs were in perfect balance with agricultural practices and sustainable management of agro-forestry (oak groves *[montado* or *dehesa],* chestnut groves, forests and woodlands). The pig husbandry was performed according to the needs of animals, soil and climatic factors and sustainable use of agro-forestry. As a result of adaptation of animals to this system, the indigenous genotypes became less prolific and their carcasses were too fat – these genetic conditions allow the maintenance of reproductive capacity of sows under difficult environmental conditions, such as the harsh climate, the shortages or seasonality of food resources.

In the second half of the twentieth century, the increasing demand for lean meat and technological developments in pig husbandry combined with major social changes of that time, led to the intensification of pig production in Europe and, in parallel, to the abandonment of traditional production systems and the decline of local genetic resources. As a result serious problems arose related to environmental pollution, with animal husbandry and animal welfare, food safety has been questioned several times and it was necessary to develop further efforts in managing food risk to consumer health. The Mediterranean region has suffered particularly with these impacts, forestry and livestock grazing losing their importance, many farms were abandoned leading to processes of erosion and desertification of land, degradation of ecosystems, loss of biodiversity of fauna and flora, and as such the Mediterranean landscape has lost some of its typical features in some places.

However in the past decade traditional systems of pig production such as extensive or agro-silvo-pastoral (*Montanheira* or *Dehesa*) has shown a renewed alternative to intensive pig production, using less external inputs and increasing the modes of sustainable management of spaces agro-forestry. These production systems have demonstrated enormous advantages in terms of diversification of niche markets (high-quality local products sold at very high prices), contributing to the viability of a large number of companies and services, from production of pigs to trading of the products. To confirm this fact we find today, in any chain of hypermarkets or small gourmet food boutiques, hundreds of references of regional pork products (sausages, hams and sliced products) associated with indigenous genotypes and/or pig production systems that are typically Mediterranean (Portugal, Spain, Italy, France, Slovenia), many of which are protected under the European community legislation (DOP and IPG) – *see DOOR database for product names registered as PDO, PGI or TSG* http://ec.europa.eu/agriculture/quality/. In this system of pig productions – *Sustainable Mediterranean* – the logic of animal management is quite different from the logic of management applied in intensive pig rearing systems. The management must be as efficient as possible, particularly from the view point of the environment and animal needs and in the choice of technology best suited to the production levels and quality characteristics, otherwise, the cost of maintenance and amortization increases without any visible economic results as expected. In this paper we discuss some of the most important aspects in the management of Mediterranean pig with a view to a good managing product qualities and the environment.

II – Traditional pig production systems in the Mediterranean

These production systems – so-called sustainable – are developed in close relation with the biotic and abiotic factors, having as their primary specificity, the ability of the local breeds to adapt to different climates and rural ecosystems and the ability of these pigs to utilize the different agro-forest resources and turn them into high quality food products. Although they use production systems that are very close to natural methods, these holdings may incorporate some advanced technologies for management in a way to permit optimization of the quality and the economy of Mediterranean pigs and also benefit the environmental balance of resources and landscape. In what concerns the functioning and the utilization of food resources, the

sustainable pig production systems in the Mediterranean area can be divided into two major groups.

(i) Extensive systems or agro-silvo-pastoral – fattening in *montanheira (PT)* or *dehesa arbolada (ES),* in which the indigenous pig, during the growth/finishing phases, utilize oak and acorns and less frequently the chestnuts, along with the grazing under the shaded areas. In general these systems predominate in the Mediterranean forests of cork oak and holm-oak (*Quercus suber* L.*, Quercus rotundifolia* L.), with the characteristic hot, dry climate and with medium to low soil fertility or with a low potential for agricultural production – manly in centre and south of the Iberian Peninsula, Corsica and Italy.

(ii) The complementary traditional farm or household production system, that does not make systematic use of forest food resources, because there are absent or scarce, but utilize more the products and by-products of local agriculture: cereals, tubers, vegetables, grass and a variety of seasonal fruits on a small scale. However, in cases of farms that have access to small woods or forests, the pigs can be placed here with a dual purpose to reap some vegetation and wild fruits (*Quercus* spp. *Castanea* spp.) and to contribute to the control of combustive material. These systems of poly-cultural production are usually associated with family farms of smaller dimensions situated in mountain regions, areas of high potential of plant biomass production in areas of micro-climates and wetter climates and soils of higher fertility – Northern Iberian Peninsula: Portugal (Trás-os-Montes, Minho), Spain (Galicia, Asturias, Basque Country), France and Italy.

The small size of the farms and the nature of the raw materials used in the traditional diet of these pig production systems has impeded the extension of the herd per farm, so in this sense, the management alternatives have been to take over the development of more intensive methods of production – intensive outdoor, camping or semi-confined – with the incorporation of technology and production factors external to the original system (e.g., cereals and food concentrates) adapted to the different physiological phases of the animals. For example, in northern Portugal small family farms associated with products from the breed with Bisaro of Origin (PDO and PGI) have increased in size by developing outdoor systems more or less intensive, often inserted in agricultural fields and small forests where the animals can graze on some herd, shrub and small fruits. In Fig. 1, we can observe the increase in average size of the Bísaro pig farms (breeding females registered in the studbook (LG), 2010), what has been achieved on the basis of increased outdoor settings.

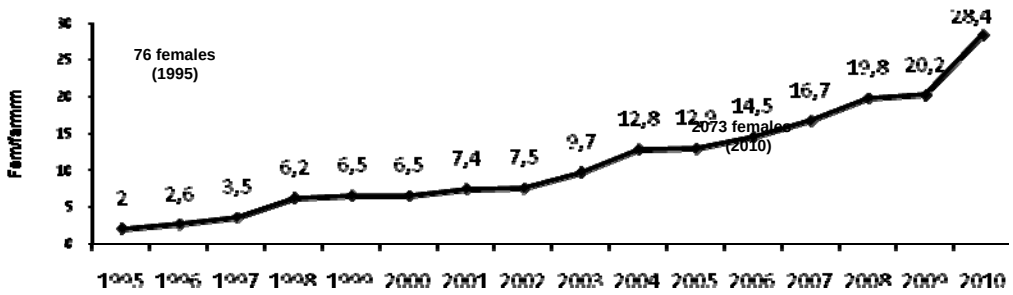

Fig. 1. Increase of the average size of the Bísaro pig farms (breeding females registered in the studbook (LG), data supplied by LG ANCSUB, 2010).

III – Animal management

The objective of animal management is to obtain a product with the highest quality and at the lowest cost, respecting the good production practices, animal welfare and the environment, taking into consideration the legal framework of the livestock sector and the market political context.

The animal husbandry is connected to how we do things to achieve a certain goal / objective, either from the standpoint of improving the effectiveness, efficiency and quality of processes and final products: guidance of fattening and finishing carcass; the conduct of reproduction and growth from birth to adult age and culling.

Animal management may have different levels of technological intervention, either using more or less land resources, more or less manpower or external production factors (capital). This sets the intensity of the use of natural resources, inputs and labor – the intensive regime, semi-intensive or extensive – which can be more or less from natural methods. The intensity of the regime used is related to the outputs ratios and obtained performances per unit of time or input, the level of technical and economic productivity and product quality. In general, compared to intensive production systems (livestock without land), traditional and sustainable pig farms in the Mediterranean involves large areas of land, using less technology and fewer external inputs.

Briefly, in an attempt to classify the main functions of animal husbandry, they may be divided on the type of technological activities and stages of the production cycle in which the animals are maintained: Global management – management planning in the farm; Planning – constitution of groups or lots of animals, social groups, number of lots, lot sizes, interval between lots; Acclimatization and buildings – housing conditions, environmental control, methods of animal containment; Culling herd – include genetic, annual replacement ratio, culling criteria, source of breeding, genotypes, genetic management – methods of crossbreeding and selection; Feeding management – *ad libitum*, restricted, semi-*ad libitum*, raw materials, diets, feeding and grazing methods, food distribution, water and watering; Reproductive management and breeding – breeding methods, assisted reproductive technology (induction, synchronization, super-ovulation, artificial insemination, pregnancy diagnosis, embryo transfer, cloning), farrowing, litters, weaning, yearling, age/weight first mating, breeding; Transport and slaughter management; Health management – preventive health, hygiene protocols, bio security measures and therapies; Management of pastures – rotations, fertilization, grazing, stocking rate; Ecosystem management – forests, mountains, "montado" or "dehesas" and specific ecosystems; Specific interventions in the animal – castration, cutting teeth and tails, markings, tattoos, chips, etc.

IV – Planning, animal management and quality improving

Animal management includes planning, programming and implementation of technological processes or tasks within the farms and has commonly been assigned a weight of over 25% in annual economic losses in the livestock sector.

A good animal management should provide a competitive advantage by incorporating technological factors and prove to be beneficial to the economy, market and society in general. In many cases, some animal management decisions seemingly simple can have very significant impacts on productivity and final quality, *eg.* the arrangement of lots, the organization of agricultural zones, the management of entry into “montanheira”, the degree of surveillance of animals, assisted reproductive technologies, the simplicity of housing, bio security plans and others. In all cases they have to be carefully chosen and well executed, otherwise may cause damage and unexpected results.

Team work skills. The proper implementation of management techniques is the key factor of pig production and depends firstly the responsibility of team managers and players (business,

engineers, veterinarians and technical staff and then planning capacity and resource management. In particular, depends on the technical and scientific knowledge held by staff, experience and training, organizational capacity and quality of implementation of each of the operations of management. Therefore, two similar farms, neighbouring each other, may have very different technical and economic results.

The pertinence of the use of certain technology management should be put up against the expected results, analyzing the cost/benefit and risk assessment. Very often, the results of operations of animal care are very different from that expected, because of poor technological applications, mismanagement or as a result of unforeseen incidents, or by direct influence of environmental factors or because of genetic interaction between animal and environment (G*A) (Hoste, 2003).

In some cases when a innovative technology is introduced on the farm, it is necessary to undertake a period of technological adaptation in the face of reality from the farm and the existing human resources, a topic that may justify the development of a research program applied for a trial period or a plan of adaptation and training of field staff.

Zoo-technical or biologic index. In short, the use of management methods requires a deep knowledge of the biology of animals and their responses to the different processes and technologies, considering the different environments and interactions. In pig production, these responses are monitored and evaluated using indicators in terms of performance efficiency, animal welfare, environmental impact, and product quality and food security, implying the existence of records and analyses tools - data collection field, computer records and analysis - that comprise the mathematical tools of management. A list of key indicators is presented in Table 1.

Table 1. Key indicators with economic interest mostly used in swine production.

Reproduction	Performances	Quality products
Semen quality, Age at puberty, Weaning-to-conception Interval, Farrowing interval, Piglets weaned, Embryonic and postnatal mortality, Numerical productivity, Ovulation rate, Litter size, Fertility rate.	Food intake, Average daily gain, Food conversion rate, Carcass losses, Live weight a certain age, Meat production per m^2, Milk production, Carcass income.	Carcass classification, Bacterial contamination, Fat (distribution), Intra muscular fat (I.M.F.), Oxidation potential, Lipid profile, Nutritional profile, pH 45 min; pH ultime, Water retention, Meat color, Tenderness, flavor and aroma.

These Indicators commonly used in swine production allow measuring the level of efficiency, effectiveness and quality of the work on the farm: ratios inputs/outputs; monitoring targets of productivity and quality and customers satisfaction. In terms of productive efficiency, the most commonly used parameters are the economic outcomes that relate the inputs consumption per unit of physical factors (per kg food, per sow, per m^2 of surface) or against periods of time (annual, monthly or per production cycle). Good examples of these indicators are the index of food conversion ratio (FCT), the average daily gain (ADG), the fertility rate (Tf) and numerical productivity (Pn). For the indicators of effectiveness and quality, parameters most used are related with the final product, such as the percentage of lean and fat and meat quality: water retention, nutritional meat profile, intra muscular fat content, colour, texture, tenderness and flavour.

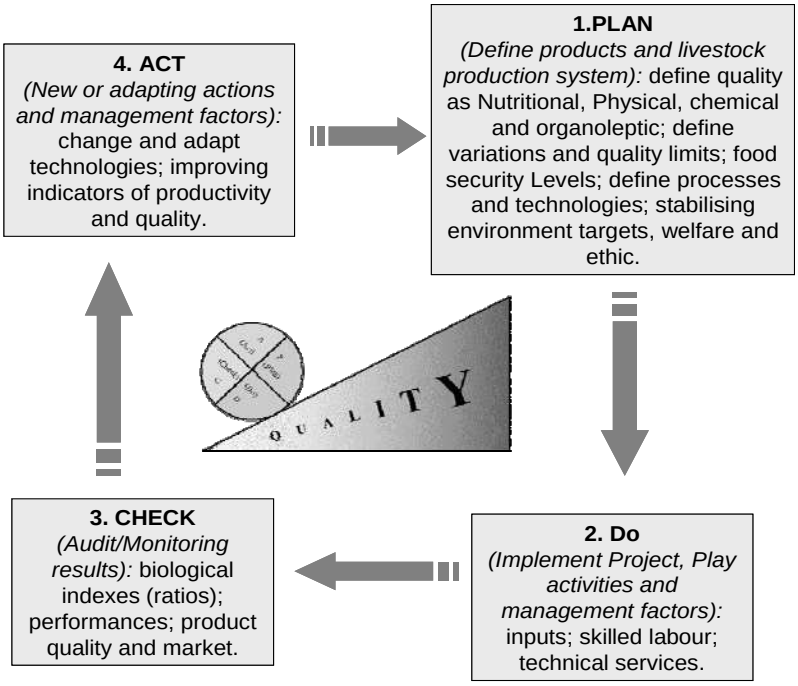

Fig. 2. PDCA cycle (Plan, Act, Check and Adapt) as a continual evaluation of the production system achieving efficient and permanent improvement of performances and quality.

The improvement processes and quality of pig production requires systematic monitoring and evaluation of results that will be obtained (via zoo-technical and quality indexes), aiming to find inefficiencies, loss of efficiency and reduced quality of products with the objective of upgrading and improving the methods of animal management used. The process of continuous quality improvement can be achieved by implementing a scheme of good quality management (Fig. 2) - the Deming's cycle or PDCA cycle (Plan, Act, Check and Adapt): 1. Plan (Define products and livestock production system; 2. Do (Project - Play activities and management factors); 3. Check (Audit/Monitoring results); 4. Act (New or adapting actions and management factors).

V – Animal husbandry, stress and animal welfare

Stress can be defined as a set of biological responses involving gene functions and hormonal responses and somatic when an individual receives a threat to its homeostasis. The threat is the factor of stress (cold, heat, equipment maladjusted to life, social interactions, pain, infection, hunger, fear) and can be rated according to their intensity and duration of its action (Moberg, 2000). Certain stressors (heat, social, fear) can alter animal behaviour and decrease food intake and/or uptake of nutrients in the gut, affecting body composition, immunity and animal welfare, and consequently affect the reproductive functions, growth and quality of final products. The negative consequences of stress are much higher when higher the intensity and duration of exposure of animals to stressors, and may have effects more or less serious, since the mere biological and regressive response, with loss of feed efficiency for repair animal welfare, to pre-pathological states or diseases, with loss of bodily functions, organ failure and death. Distress

may occur at any stage of production process, during transport or in slaughterhouses. The main purpose of animal welfare management is to prevent and reverse the stress situations in order to improve the well-being, the performances and quality.

The implementation of most husbandry activities requires physical and psychological contact between man and animals likely to cause fear and pain, which in itself is a major stress factor. This is extremely important and raises important questions from the ethological and ethical point of view, related to the way we relate to animals, and the conduct that we have during the production process. Negligence, greed and accidents cause a large number of physical and metabolic lesions in the animals, which causes irreparable economic losses. However, in animal production, very often it is necessary to cause a short term pain (acute stress), to obtain the productive benefits in the long run. Some good examples of this are castration, health interventions, treatments and interventions for specific management, such as putting tags or tattoos. In these cases, whereas inevitable, good management practices indicate that these operations should be held as soon as possible, in safety to the operator and to animals, with minimal pain and done by trained personnel (Gregory, 1998). The way how animals are treated, have a great impact on the economy and competitiveness in the pork meat chains and are particularly sensitive in the public mind, consumer and society. That's why since 1991, the European Council published the first Directive setting out specific minimum standards for the welfare of pigs (Directive 91/630/EEC), which are legally binding on all member states. This legislation contains the basic principles of standards of protection and management of pigs for housing, handling and husbandry of the pigs: origin of stock, stockman ship and welfare, health and veterinary supervision, stock accommodation and handling facilities, feeding and water provision and farm cleanliness.

The outdoor pig rearing systems, the most used in the Mediterranean, are potentially more comfortable and have a lower initial investment cost, provide a greater enrichment of the environment, more space and opportunity to practice exercises of pigs. However, some disadvantages may also be considered: a greater risk of sunburn and heat stress, increased frequency of aggression and bullying. The outdoor hinders the feeding of sows individually, hinders the inspection of each animal and individualized treatment becomes more difficult. All these variables must be addressed and resolved through effective management and husbandry techniques should be more specific.

VI – Climatic factors in the Mediterranean and the husbandry of pigs

A major concern of pig production that should be considered in the Mediterranean region is the adaptation of the management techniques to the objectives of animal husbandry, the environment and the economics of the traditional and extensive or outdoor production systems.

The effect of heat stress causes a decrease in feed intake, alters the activity and social behaviour of animals, causes considerable losses of fertility, delayed growth, and changes the composition of carcass and meat quality. The problems of high temperatures during the transportation of animals to slaughterhouses increase the economic and quality losses of the final products (Gregory, 1998). For this reason the animal welfare during transport can not be neglected, and special attention should be done to the physical conditions of vehicles and animal handling, animal density, the distances travelled and time of travel. The very high temperatures, above the zone of thermal comfort of pigs, often associated with heat waves and periods of extreme drought are the main climatic stress factors affecting livestock pig production in southern Europe, estimating that their effects on gross annual loss of domestic product may exceed 20%: decrease of the performance, meat quality and reproduction losses, loss of production of cereals, pastures, fodder and forest fruits (Barbosa *et al.,* 2008).

The mobilization of body stores of lactating sows depends on the genotypes, the weather and the season and influences the prolificacy and fertility of sows, including anoestrus and the interval between weaning and ovulation (Santos Silva, 2006). The fact that native breeds have more body reserves and increased capacity to mobilize them evidenced a greater adaptive advantage of these animals to more extensive production systems, highly dependent on the variations of climate and food resources throughout the year. This ability to mobilize body reserves is linked to the adaptive capacity of local pig breeds to extreme environment conditions and can be understood by rusticity. Climate variations over the year and from year to year affect the results growth (ADG), deposition of fat and percentage of muscle and meat quality parameters as collagen and myofibrils fragment value (Santos Silva, *et al.,* 2006). Thus, under outdoor conditions, the seasonality is an important source of variation in performance and quality, the practices of animal husbandry should be based on the impact it can have on the agro-forestry resources and on the production of animals must adapt in terms of edaphologic and water resources, the potential of vegetal biomass production – cereals, grass and forest fruits (acorns, oaks and chestnuts) – with special attention to feeding management, grazing management and environmental adaptation of the animals to climatic variations.

VII – Animal husbandry and meat quality

The Mediterranean production systems which enhances the value of endogenous resources and ecosystems are increasingly appreciated by the society, due to the beneficial role they play in the environment and the lives of animals (ethical quality), and to the associated nutritional and organoleptic quality. The type of breed (local Mediterranean genotypes or crossbreeds), age and weight at slaughter, the climatic conditions, the use of regional raw materials (acorns, oaks, chestnuts, grass and agricultural by-products) and the exercise that the animals can do during grazing, are the main differentiating factors of meat quality of Mediterranean pigs. In general the pigs destined for the high-quality products (PDO, PGI) are slaughtered at weights well above the age of sexual maturity (120-160 kg BW), when muscle growth has stabilized and at the expense of greater capacity of deposition and infiltration of intramuscular fat (+ 60% monounsaturated), an essential condition in order to develop the organoleptic characteristics – aroma, flavor, color, brightness, texture – highly valued in the market by the great appreciators (Tirapicos Nunes, 2007).

VIII – Reproductive performances

For many centuries, swine production systems and the husbandry of pigs were performed according to the needs of animals, soil and climatic factors and sustainable use of agro-forestry. As a result of adaptation of animals to this system, the indigenous genotypes became less prolific and their carcasses were too fat – these genetic characteristics allow the maintenance of reproductive capacity of sows under difficult environmental conditions, such as the harsh climate, the shortages or seasonality of food resources. On the basis of genetic factors such as low genetic potential and the high consanguinity resulting from small herds that constitute the native breeds, are considered the main reasons for the low reproductive performances in local breeds. Reproductive traits such as the low ovulation rates and conception, high rate of embryo mortality and low survival rates after birth, failure in milk production and reduced postnatal growth are the main causes of loss in performance (Ollivier *et al.,* 2001). Other environmental factors related to seasonal climatic factors, with poor management or mismanagement of the production systems – poor nutrition, poor acclimatization, poor application of reproductive techniques, poor health standards and low levels of animal welfare – contribute to a greater extent to loss of productivity of the breeding sows. Limited by genetic factors, because selection of the reproductive traits are of low heritability, the improvement of environmental management and application of reproductive techniques are the most effective ways to improve reproductive outcomes in the short term.

Another option to improve reproductive performance in maternal lines in just one generation is the use of crosses between breeds (local x exotics breeds). In this case the breeds more used for obtaining breeding sows (F1) are the Large White breed and different lines of Landrace. However, these crossbreeding can alter the final quality of the products, especially if companies decided by supply pig meat chains only with purebreds. Duroc breed is most commonly used for terminal crosses with the aim of improving performances of growth and carcass (Martínez Serrano, 2008). In this case, the improvements are also obtained in terms of survival rate of piglets, as they have more vitality and viability due to the phenomenon of heterosis.

IX – General conclusions

The future of the Mediterranean production systems based on Multiple Use of Forest – pig meat production, management of combustible material, energy production, timber production, fruits, bark, biodiversity, agriculture, recreation and landscape – depend on the political and social consciousness of the local populations, the quality of the multifunctional management of agro-forestry resources and the maintenance of a healthy original ecosystem. As a general rule of good planning and animal management, the economic benefits of the pig production management practiced should be higher than the accrued costs of its introduction and should not interfere with the final quality of the products.

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