UNIVERSIDAD DE CÓRDOBA

Programa de Doctorado Recursos Naturales y Gestión Sostenible

"Caracterización y eficiencia de agroecosistemas para una producción de cerdos Ibéricos más sustentable"

"Characterization and efficiency of agroecosystems for a greater sustainability of Iberian pig production"

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TITULO: *CARACTERIZACIÓN Y EFICIENCIA DE AGROECOSISTEMAS PARA UNA PRODUCCIÓN DE CERDOS IBÉRICOS MÁS SUSTENTABLE*

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TÍTULO DE LA TESIS: CARACTERIZACIÓN Y EFICIENCIA DE AGROECOSISTEMAS PARA UNA PRODUCCIÓN DE CERDOS IBÉRICOS MÁS SUSTENTABLE

DOCTORANDO: JAVIER GARCÍA GUDIÑO

INFORME RAZONADO DE LOS DIRECTORES DE LA TESIS

La tesis doctoral se ha llevado a cabo en el marco establecido por el proyecto "*Nuevas estrategias y metodologías nutricionales, reproductivas y de la eficiencia del sistema para la mejora de la sostenibilidad socioeconómica y ambiental de explotaciones de cerdos Ibéricos de elevada calidad*" (RTA2013-00063-C03) financiado por INIA, y el programa de formación de investigadores en agroalimentación en los centros de investigación agraria y alimentaria INIA-CCAA (FPI-INIA) que financia una beca predoctoral al amparo del mencionado proyecto.

La tesis doctoral hace una aportación significativa al conocimiento de la producción porcina ibérica de la dehesa desde un enfoque integrado en el que se combina la sostenibilidad de los sistemas de producción con la competitividad de los productos derivados, así como las preferencias de los consumidores. En la memoria de tesis el doctorando aborda mediante diferentes instrumentos metodológicos algunos de los principales problemas de la producción porcina de la dehesa, para después vincular los resultados con el comportamiento del consumidor y conseguir una visión más completa de lo que es estratégico para el sector. El doctorando ha realizado un importante esfuerzo académico que le permite aportar resultados significativos sobre el agroecosistema evaluado, los impactos y usos ganaderos observados, y el papel que el consumidor puede desempeñar como garante de la conservación.

Debido a la variedad de temas incluidos en la tesis, a lo largo de la realización de ésta, el doctorando ha adquirido las habilidades y competencias necesarias propias del grado de doctor, quedando plenamente capacitado para identificar, planificando y ejecutando tareas de investigación, analizando los datos y resolviendo problemas de la producción animal mediante métodos de investigación y comunicar los resultados en los medios habituales de la ciencia. Como parte de su plan de formación, destaca la Estancia de 3 meses en INRA-PEGASE en Saint-Gilles (Francia) centrada en la evaluación medioambiental de los sistemas de producción extensivos del cerdo Ibérico a través de LCA.

Además de los artículos que forman parte de la memoria de tesis doctoral, la tesis ha dado lugar a los siguientes trabajos:

ARTÍCULOS CIENTÍFICOS REVISADOS POR PARES:

Font-i-Furnols, M; **García-Gudiño, J**; Izquierdo, M; Brun, A; Gispert, M; Blanco-Penedo, I; Hernández-García, F.I. "*Non-destructive evaluation of carcass and ham traits and meat quality assessment applied to early and late immunocastrated Iberian pig*" Animal **2021**, 100189. https://doi.org/10.1016/j.animal.2021.100189

PUBLICACIONES TÉCNICAS:

García-Gudiño, J; Font-i-Furnols, M; Brun, A; Gispert, M; Perea-Muñoz, J; Blanco, I; "*Visión de los consumidores: ¿puede cambiar la elección de un alimento su modo de producción?*" **2017**. Revista Solo Cerdo Ibérico 38:108-114. ISBN: 84-930710-0-5

García-Gudiño, J; Perea-Muñoz, J; Gispert, M; Font-I-Furnols, M; Blanco, I; "*Caracterización y eficiencia de agroecosistemas para una producción de cerdos Ibéricos más sustentable*" **2016**. Revista Solo Cerdo Ibérico 35:78-82. ISBN: 84-930710-0-5.

COMUNICACIONES EN CONGRESOS INTERNACIONALES:

Font-i-Furnols, M; **García-Gudiño, J**; Gispert, M; Brun, A; Hernández-García, F.I; Izquierdo, M; Blanco-Penedo, I. "*Effect of the immunocastration protocols on ham composition evaluated with computed tomography*" 4th Fatty Pig Science and Utilization International Conference. 23-25 noviembre **2017**, Badajoz, España.

COMUNICACIONES EN CONGRESOS NACIONALES:

García-Gudiño, J; Matías, J; Izquierdo, M; Pérez, M.A; Hernández-García, F. "*Uso de subproductos agrarios como estrategia alimentaria durante la premontanera en el cerdo Ibérico*" XIX Jornadas AIDA sobre Producción Animal. 1-2 junio **2021**. Versión on-line.

García-Gudiño, J; Izquierdo, M; Blanco-Penedo, I; Hernández-García, F.I. *"¿Es posible reducir los impactos medioambientales en la producción del cerdo Ibérico en la dehesa?*" VIII Remedia Workshop. 22-23 septiembre **2020**. Elche, España. On-line Open Edition. ISBN 978-84-09-20058-0

García-Gudiño, J; Blanco-Penedo, I; Perea-Muñoz, J; Hernández-García, F.I; Matías, J; Izquierdo, M. "*La cascarilla de arroz como estrategia alimentaria en el cerdo Ibérico durante la premontanera: Estudio comportamental y valoración del Bienestar animal*" XVII Jornadas sobre Producción Animal. 30-31 mayo **2017**. Zaragoza, España. Comunicación oral. ISBN: 978-84-697-3065-2

García-Gudiño, J; Font-i-Furnols, M; Gispert, M; Brun, A; Perea-Muñoz, J; Blanco-Penedo, I. "*El consumidor frente a la Norma de Calidad del Ibérico*" V Congreso de la Asociación Nacional de Veterinarios de Porcino. 23-24 noviembre, **2016**. Córdoba, España.

POSTERS EN CONGRESOS INTERNACIONALES:

García-Gudiño, J; Blanco-Penedo, I; Angón, E; Perea, J. "*Multivariate indices in technical-economic and structural traits of Iberian pig: preliminary results*" EAAP 71th Annual Meeting of the European Federation of Animal Science. 1 - 4 diciembre **2020**. Virtual Meeting. ISBN: 978-90-8686-349-5

García-Gudiño, J; Gispert, M; Brun, A; Blanco-Penedo, I; Hernández-García, F; Izquierdo, M; Font-i-Furnols, M. "*Non-destructive technologies to evaluate hams' characteristics from immunocastrated Iberian pigs*" EAAP 71th Annual Meeting of the European Federation of Animal Science. 1 - 4 diciembre **2020**. Virtual Meeting. ISBN: 978-90-8686-349-5

Angón, E; **García-Gudiño, J**; Blanco-Penedo, I; E; Perea, J. “*Eco-efficiency assessment of Iberian pig production in Spanish dehesa: preliminary results*” EAAP 71th Annual Meeting of the European Federation of Animal Science. 1 - 4 diciembre **2020**. Virtual Meeting. ISBN: 978-90-8686-349-5

García-Gudiño, J; Monteiro, A.N.T.R; Espagnol, S; Blanco-Penedo, I; Garcia-Launay, F. “*Environmental Assessment of traditional Iberian pig production in Spain with two different fattening systems*” 12th International Conference on Life Cycle Assessment of Food 2020 (LCA Food 2020). 13-16 octubre **2020**. Berlin, Alemania - Virtual formato. ISBN: 978-3-00-067604-8

García-Gudiño, J; Blanco-Penedo, I; Monteiro, A; Espagnol, S; Garcia-Launay, F. “*Environmental impacts of contrasted Iberian pig production systems*”. X International Symposium on the Mediterranean Pig. 16-19 octubre **2019**. Florencia, Italia. ISBN 978-88-944823-0-0

García-Gudiño, J; Izquierdo, M; Matías, J; Cruz, V; Pérez, M.A; Pardo, S; Hernández-García, F.I. “*Optimization of Iberian pig extensive systems during the growing period: use of alternative protein sources through grazing*”. X International Symposium on the Mediterranean Pig. 16-19 octubre **2019**. Florencia, Italia. ISBN 978-88-944823-0-0

García-Gudiño, J; Velarde, A; Fonts-i-Furnols, M; Blanco-Penedo, I. “*Effect of fattening management on animal welfare of Iberian pigs*”. EAAP 69th Annual Meeting of the European Federation of Animal Science. 27-31 agosto **2018**. Dubrovnik, Croacia.

Font-i-Furnols, M; **García-Gudiño, J**; Brun, A; Gispert, M; Perea, J; García-Casco, J; González, E; Blanco-Penedo, I. “*Low protein and “alperujo” diet do not affect consumers´acceptability of Iberian crossbreed dry-cured loins*” 63rd International Congress of Meat Science and Technology 13 - 18 agosto **2017**. Cork, Irlanda.

García-Gudiño, J; Izquierdo, M; Hernández-García, F.I; Velarde, A; Galindo, F; Blanco-Penedo, I. “*Behaviour of the Iberian pig during montanera*” 4th Fatty Pig Science and Utilization International Conference. 23-25 noviembre **2017**, Badajoz, España.

García-Gudiño, J; Font-i-Furnols, M; Gispert, M; Brun, A; Hernández-García, F.I; Izquierdo, M; Blanco-Penedo, I. “*Effect of the immunocastration protocols on consumers’ acceptability of fresh loin from Iberian pigs*” 4th Fatty Pig Science and Utilization International Conference. 23-25 noviembre **2017**, Badajoz, España.

García-Gudiño, J; Font-i-Furnols, M; Gispert, M; Brun, A; Perea-Muñoz, J; Blanco-Penedo, I. “*Awareness about sustainability in pork consumers*” 9th International Symposium on Mediterranean Pig. 3-5 noviembre, **2016**. Portalegre, Portugal. ISBN: 978-989-8806-11-6.

Font-i-Furnols, M; **García-Gudiño, J**; Brun, A; Blanco-Penedo, I; Perea-Muñoz, J; García-Casco, J; González, E; Gispert, M. *“Segmentation of consumers according to their purchasing intention for type of pork, rearing conditions and price”* 9th International Symposium on Mediterranean Pig. 3-5 noviembre, **2016**. Portalegre, Portugal. ISBN: 978-989-8806-11-6.

Brun, A; **García-Gudiño, J**; Gispert, M; Blanco-Penedo, I; Font-i-Furnols, M. **“***Ham composition of Iberian pigs fed different diets evaluated with computed tomography”* 9th International Symposium on Mediterranean Pig. 3-5 noviembre, **2016**. Portalegre, Portugal. ISBN: 978-989-8806-11-6.

Gispert, M; **García-Gudiño, J**; Blanco-Penedo, I; Perea-Muñoz, J; García-Casco, J; González, E; Brun, A; Font-i-Furnols, M. "*Effect of the diet on the consumer acceptability of fresh loin from Iberian pigs*" 67th Annual Meeting of the European Federation of Animal Science. 29 agosto – 2 septiembre, **2016**. Belfast, Reino Unido ISBN: 978-90-8686-830-8.

POSTERS EN CONGRESOS NACIONALES:

García-Gudiño, J; Brun, A; Gispert, M; Perea, J; Blanco-Penedo, I; Font-i-Furnols, M "*¿Quién vive en zona de dehesa conoce mejor al cerdo ibérico?*" IX ANVEPI. 26-27 abril **2017**. Toledo, España.

García-Gudiño, J; Font-i-Furnols, M; Gispert, M; Brun, A; Perea-Muñoz, J; Blanco-Penedo, I. "*¿Cómo puede llegar a influir el Bienestar Animal en la elección de compra de un producto?"* V Congreso de la Asociación Nacional de Veterinarios de Porcino. 23-24 noviembre, **2016**. Córdoba, España.

García-Gudiño, J; Blanco-Penedo, I; Perea-Muñoz, J. "*Preferencia de compra y consumo de porcino en España*" V Congreso Científico de Investigadores en Formación de la Universidad de Córdoba. 30 nov-1,2 diciembre, **2016**. Córdoba, España. Póster. ISBN: 978-84-9927-271-9.

Si a todo esto se añaden los tres artículos publicados más los tres enviados que forman los resultados de la tesis doctoral, consideramos que reúne méritos más que suficientes para que el doctorando reciba el grado de doctor obteniendo la máxima calificación.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, 11 de mayo de 2021

Firma de los directores

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La realización de esta tesis doctoral ha sido posible gracias al proyecto "*Nuevas estrategias y metodologías nutricionales, reproductivas y de la eficiencia del sistema para la mejora de la sostenibilidad socioeconómica y ambiental de explotaciones de cerdos Ibéricos de elevada calidad*" financiado por el Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (**RTA2013-00063-C03**). La tesis doctoral ha sido desarrollada en el Institut de Recerca i Tecnología Agroalimentàries y en el Departamento de Producción Animal de la Universidad de Córdoba.

A mi abuelo Mariano

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A mi familia, por ser los pilares de lo que soy.

A mis padres y a mi hermana, por su apoyo incondicional.

A Raúl, por su infinita paciencia y ser el mejor compañero de vida.

Listado de abreviaturas

AWU	Annual Work Unit
CC	Climate Change
CED	Cumulative Energy Demand
CML	Institure of Environmental Sciences
CP	Crude Protein
CV	Coefficient of Variation
DEA	Data Envelopment Analysis
DF	Diversified Farms
DM	Dry Matter
DMU	Decision Making Unit
EU	Eutrophication
GLM	Generalized Linear Model
ILCD	Intenational reference Life Cycle Data system
kg	kilogram
KMO	Kaiser-Meyer-Olkin
LCA	Life Cycle Assessment
LO	Land Occupation
LU	Livestock Unit
LW	Live Weight
MF	Montanera Farms
NE	North-East
OM	Organic Matter
PCA	Principal Component Analysis
PDO	Protected Designation of Origin
$\mathbf{R^2}$	Coefficient of determination
RMSE	Root Mean Square Error
rPAR	Pearson correlation coefficient partial
rPEAR	Pearson correlation coefficient
SD	Standard Deviation
SDG 12	Sustainable Goal Development 12
SDGs	Sustainable Development Goals
SE	Standard Error
SDM	Squared Deviation from the Mean

Índice

Introducción

Justificación

La producción del cerdo Ibérico data de tiempos inmemoriales. Existen referencias históricas de la época de la dominación romana, a través del escritor hispanorromano Columela. El sistema tradicional de cría y reproducción del cerdo Ibérico se caracteriza por desarrollarse en las dehesas del suroeste de la península ibérica (Benito et al., 2006). Las dehesas pueden ser definidas como áreas boscosas abiertas de árboles pertenecientes a la familia *Quercus*, con un estrato arbustivo escaso y una cubierta vegetal de especies herbáceas (Rodríguez-Estévez et al., 2009) donde diferentes especies ganaderas son explotadas a través del aprovechamiento de los recursos naturales que ofrece este sistema agrosilvopastoril (Horrillo et al., 2020). El cerdo Ibérico ha sido la raza porcina tradicionalmente criada en la dehesa por el óptimo uso que realiza de los recursos naturales de este singular agroecosistema (Rodríguez-Estévez et al., 2007), debido a que las razas autóctonas están localmente adaptadas a los agroecosistemas locales (Velado-Alonso et al., 2020).

A mediados del siglo XX se produjo un cambio de orientación en la producción porcina española. Se transitó de un sistema de producción extensivo en el suroeste español a un sistema intensivo en el noreste del país (Ríos-Núñez & Coq-Huelva, 2015). La deslocalización de la producción porcina española fue ocasionada por la necesidad de proximidad a los puertos marítimos, a causa de una mayor dependencia de materias primas (Sporchia et al., 2021) y al convertirse en un sector con orientación exportadora (MAPA, 2020). De este modo, España se ha convertido en el cuarto país productor de porcino a nivel mundial y segundo de Europa (EUROSTAT, 2020). En la actualidad, los sistemas industriales con genotipos híbridos son los predominantes, aunque la producción tradicional del cerdo Ibérico sigue teniendo un papel importante en el sector porcino español (MAPA, 2020). La adaptación del cerdo Ibérico al agroecosistema de la dehesa junto a las preferencias del consumidor por productos más éticos y de mayor calidad sensorial han favorecido la pervivencia de esta raza local y su sistema productivo (Rodriguez-Estevez et al., 2012).

La propia producción porcina Ibérica también se ha transformado en las últimas décadas, alcanzando un 10% del total de cerdos producidos en España (MAPA, 2020). La principal causa es el aumento de demanda de sus productos (Ventanas et al., 2005) por diferentes aspectos como la gran calidad y variedad de sus productos (Lorido et al., 2015) o la buena imagen de las prácticas ganaderas de este sistema porcino tradicional (Díaz-Caro et al., 2019). La limitación de hectáreas disponibles de dehesa para producir cerdos Ibéricos exclusivamente con recursos naturales (Mesías et al., 2009) ha generado diferentes modos de producción (Tejerina et al., 2012).

En la actualidad, el sector Ibérico se encuentra regulado a través de la Norma de Calidad del Ibérico (Real Decreto 4/2014). Esta regulación ha provocado un aumento del 30% en el número de animales producidos desde su implantación (RIBER, 2020), derivado de la autorización del cruzamiento con la raza Duroc, y una producción más intensiva fuera del agroecosistema de la dehesa (Nieto et al., 2019). Como consecuencia, el sistema de producción tradicional basado en el engorde de cerdos Ibéricos puros a base de recursos naturales ha pasado a ser minoritario; hoy en día solo una décima parte de los cerdos son producidos de este modo (RIBER, 2020).

De los 3,6 millones de cerdos producidos el año 2020 en la península ibérica, el 60% fueron producidos a base de piensos compuestos de manera industrial. La producción restante corresponde a sistemas más o menos extensivos de la zona tradicional del cerdo Ibérico (RIBER, 2020). Debido a que la superficie de dehesa es limitada (Mesías et al., 2009), la mitad de estos cerdos Ibéricos fueron engordados principalmente con piensos compuestos y un menor porcentaje de recursos naturales (Real Decreto 4/2014), aumentando de esta manera la capacidad productiva de la dehesa. Aunque la presencia del cerdo Ibérico se reconoce como un factor clave para la sostenibilidad de la dehesa (Gaspar et al., 2007), la sobreexplotación y la falta de rentabilidad están poniendo en peligro el equilibrio de este agroecosistema tan singular (Ibáñez et al., 2014; López-Sánchez et al., 2014). La necesidad de garantizar una producción de cerdos Ibéricos más sostenible y competitiva dio lugar al proyecto "*Nuevas estrategias y metodologías nutricionales, reproductivas y de la eficiencia del sistema para la mejora de la sostenibilidad socioeconómica y ambiental de explotaciones de cerdos Ibéricos de elevada calidad*" (**RTA2013-00063-C03**) mediante el cual esta tesis ha evaluado de manera multidisciplinar el sector del cerdo Ibérico para alcanzar una producción porcina Ibérica más sostenible.

La Unión Europea fomenta métodos de producción agrarios más sostenibles mediante diferentes instrumentos financieros de la Política Agraria Común (PAC) y del Fondo Europeo Agrícola de Desarrollo Rural (FEADER). Para ello, es necesario que se incluyan medidas que garanticen el equilibrio agroecológico de los sistemas agrarios (Horrillo et al., 2020), potenciando y compensando económicamente sus características ambientales con el fin de aumentar los bajos ingresos que obtienen estas explotaciones (Scown et al., 2020). En este sentido, la nueva PAC tiene un importante potencial para contribuir a un desarrollo sostenible en la ganadería europea dado que combina planteamientos sociales, económicos y medioambientales. Con este enfoque combinado, la PAC adapta la agricultura al Pacto Verde Europeo que pretende sentar las bases de un sistema alimentario sostenible a través de la estrategia "De la granja a la mesa" (Comisión Europea, 2019). El cambio hacia un sistema alimentario sostenible debería aportar beneficios ambientales, económicos y sociales.

En este sentido, el sistema tradicional productivo del cerdo Ibérico es un modelo muy atractivo para ser estudiado ya que se trata de una práctica ganadera integrada en el agroecosistema único de la dehesa. Para ello, es necesario investigar el sistema de producción tradicional con una metodología transversal que evalúe el ciclo productivo en su conjunto, ya que el cerdo Ibérico y el agroecosistema de la dehesa forman un tándem necesario para la continuidad de ambos (Rodriguez-Estevez et al., 2012).

Por todo ello, la búsqueda de mejoras en el sector porcino Ibérico desde un punto de vista ambiental, económico y social son primordiales para asegurar un futuro a largo plazo del sistema tradicional del cerdo Ibérico, investigando planes estratégicos en todo el circuito alimentario, desde la producción hasta los consumidores del producto final. Desde un punto de vista ambiental, las producciones tradicionales han mostrado, en general, mayores impactos medioambientales que los sistemas convencionales (Dourmad et al., 2014), aunque estas razas locales explotadas de manera extensiva y haciendo uso de los recursos naturales disponibles (Espagnol & Demartini, 2014) muestran margen de mejora (Monteiro et al., 2019). Desde un punto de vista económico, los sistemas alternativos suelen obtener una menor rentabilidad que los sistemas convencionales (Wei et al., 2016). Pero hay que tener en cuenta que productos de calidad como los del cerdo Ibérico tienen un mayor valor en el mercado (Gaspar et al., 2009b), lo que debería repercutir positivamente en la rentabilidad de este tipo de explotaciones. Por último, una parte fundamental del pilar social en el desarrollo sostenible son los consumidores, en los cuales, la concienciación sobre las diferentes formas de producción de los alimentos está aumentando (Pejman et al., 2019).

Actualmente se disponen de diferentes herramientas para realizar una evaluación de la sostenibilidad en el sistema tradicional Ibérico. El punto de partida es una tipología de sistemas de producción que permita caracterizar y evaluar comparativamente la capacidad de continuidad de los sistemas de porcino Ibérico (García et al., 2010). Esto se lleva a cabo en el capítulo segundo mediante la publicación "*Structural typologies of Iberian traditional pig farms accounting their association with the economic and environmental performance*".

Una vez identificadas las alternativas del ecosistema, se cuantifica y evalúa el impacto ambiental de la producción porcina. Para ello se utiliza el Análisis de Ciclo de Vida porque es la metodología más reconocida para hacerlo (McAuliffe et al., 2016). Esto se lleva a cabo en el capítulo primero mediante la publicación "*Life Cycle Assessment in Iberian traditional pig production system in Spain*".

La integración de los diferentes impactos medioambientales con los aspectos técnicos y económicos de los sistemas de producción da lugar a una evaluación global que combina la sostenibilidad con la competitividad, potenciando la formulación de estrategias a largo plazo para conseguir un efecto ambiental y socioeconómico positivo. Esta integración es posible a través de técnicas de análisis multivariante para analizar las diferencias y similitudes entre las diferentes áreas -ambientales, técnicas y económicas- del sistema de producción (Zurita-Herrera et al., 2011). Esto se lleva a cabo desde un punto de vista más descriptivo en el capítulo tercero mediante la publicación "*Analysis of the sustainability of fattening systems for Iberian traditional pig production through a technical and environmental approach*".

Desde un punto de vista más operativo, mediante el empleo de técnicas econométricas basadas en fronteras no paramétricas, se evaluó el nivel de ecoeficiencia de los sistemas de producción, lo que permite identificar los procesos y prácticas ganaderas que optimizan la producción porcina desde el punto de vista técnico y ambiental, simultáneamente. Este enfoque fortalece la adopción de prácticas ganaderas más sostenibles a la vez que más competitivas (Angón et al., 2015; Gaspar et al., 2009a). Esto se lleva a cabo desde un punto de vista más descriptivo en el capítulo cuarto mediante la publicación *"Targeting environmental and technical parameters through eco-efficiency criteria for Iberian pig farms in the dehesa ecosystem"*.

Por otro lado, es necesario realizar un estudio de las preferencias de los consumidores con respecto a los productos cárnicos de origen porcino en España para adaptar la producción porcina Ibérica a las demandas del mercado actual. La percepción del consumidor hacia sistemas de producción porcina al aire libre es positiva (Argemí-Armengol et al., 2019) en comparación con los sistemas convencionales (Clark et al., 2019). Además, la raza puede influir en la decisión de compra de los alimentos (Lee et al., 2017). Por todas estas razones, la utilización de técnicas como el Análisis conjunto (Font i Furnols et al., 2011) son necesarias para determinar las preferencias actuales del consumidor. Esto se lleva a cabo en los capítulos quinto y sexto mediante las publicaciones *"Undestanding consumers' perceptions towards Iberian pig production and animal welfare" y "Exploring sustainable food choices factors and purchasing behaviour in the Sustainable Development Goals era in Spain"*, respectivamente.

Por todo ello, debemos señalar que realizar una valoración global del sistema productivo tradicional del cerdo Ibérico es esencial, con el fin de que esta producción ganadera asentada en un agroecosistema tan singular como es la dehesa sea más sostenible.

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Objetivos

El objetivo principal de esta tesis doctoral es la caracterización de la producción porcina en el ecosistema de la dehesa con el fin de alcanzar una producción de cerdos Ibéricos más sustentable. Para conseguir este objetivo general se plantearon varios objetivos específicos, desarrollados en las publicaciones incluidas en la tesis:

Objetivo 1.- Evaluar los impactos medioambientales en la producción tradicional del cerdo Ibérico en comparación con otros sistemas productivos porcinos, teniendo en cuenta la contribución de las emisiones resultantes por el consumo de los recursos naturales procedentes de la dehesa (Capítulo primero).

Objetivo 2.- Identificar diferentes tipologías de ganaderías tradicionales de cerdo Ibérico en base a aspectos técnicos, productivos y económicos con el fin de analizar los impactos ambientales generados y los beneficios económico-ambientales correspondientes a los diferentes tipos de ganaderías porcinas establecidos (Capítulo segundo).

Objetivo 3.- Estudiar las diferencias entre los diferentes tipos de cebos realizados en las ganaderías tradicionales de cerdo Ibérico desde un punto de vista técnico-económico y ambiental, identificando características como puntos de referencia para diferenciar los diferentes tipos de cebo con el fin de proponer estrategias para mejorar la sostenibilidad de la producción de cerdo Ibérico tradicional (Capítulo tercero).

Objetivo 4.- Evaluar la ecoeficiencia de la producción porcina extensiva en la dehesa a través de una combinación metodológica del Análisis de Ciclo de Vida y el Análisis Envolvente de Datos, determinando factores causantes de la ineficiencia (Capítulo cuarto).

Objetivo 5.- Determinar las percepciones de los consumidores sobre aspectos de la producción del cerdo ibérico y el bienestar animal en base al grado de conocimiento de los consumidores sobre la producción del cerdo ibérico y sus características demográficas. Determinar la importancia relativa de la raza, el sistema de producción y el precio a la hora de comprar productos, en función de las características de los consumidores (Capítulo quinto).

Objetivo 6.- Identificar tipologías significativas de patrones de consumo en el marco de los Objetivos de Desarrollo Sostenible, y conocer cómo se asocian los diferentes atributos de los sistemas agropecuarios con dichas tipologías (Capítulo sexto).

Aims

The PhD thesis aims to characterise the Iberian pig production in the *dehesa* ecosystem in order to achieve a sustainable production of Iberian pigs. The following specific aims were developed in the publications included in this PhD thesis:

Aim 1.- To evaluate environmental impacts of Iberian traditional pig production in comparison to others pig production systems, while accounting for the contribution of emissions resulting from the consumption of natural resources from the *dehesa* (First chapter).

Aim 2.- To identify different typologies based on technical, productive and economic aspects in Iberian traditional pig farm in order to analyse the environmental impacts generated and their economic-environmental benefits according to the Iberian farm type system (Second chapter).

Aim 3.- To explore the differences in fattening types in Iberian traditional pig farms based on technical-economical and environmental approach, identifying the characteristics that can be reference points to differentiate the fattening types in order to propose strategies to improve sustainability of Iberian traditional pig production (Third chapter).

Aim 4.- To evaluate the eco-efficiency of extensive pig production in the *dehesa* through Life Cycle Assessment and Data Envelopment Analysis, analysing the determinants of inefficiency (Fourth chapter).

Aim 5.- To determine the perceptions of consumers towards several aspects of Iberian pig production and animal welfare depending on the consumers' degree of knowledge about Iberian pig production and their demographic characteristics. Furthermore, to determine the relative importance of the breed, production system and price when purchasing products, depending on consumers' characteristics (Fifth chapter).

Aim 6.- To identify meaningful typologies of consumption patterns framed by Sustainable Development Goals and to know how different farm systems attributes are associated with such typologies (Sixth chapter).

Capítulos

Capítulo primero

Life Cycle Assessment of Iberian traditional pig production system in Spain

Javier García-Gudiño; Alessandra N.T.R. Monteiro; Sandrine Espagnol; Isabel Blanco-Penedo; Florence Garcia-Launay

Sustainability 2020, *12*, 627

Life Cycle Assessment of Iberian traditional pig production system in Spain

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Abstract: Traditional Iberian pig production is characterized by outdoor systems that produce animals fed with natural resources. The aim of this study was to assess the environmental impacts of such systems through Life Cycle Assessment. Environmental impacts were analysed per kilogram of live weight at farm gate. Iberian pig production in *montanera* had the lowest impacts for climate change (CC), acidification (AC), eutrophication (EU) and cumulative energy demand (CED), being 3.4 kg CO_2 eq, 0.091 molc H^+ eq, 0.046 kg PO_4^{3-} eq, and 20.7 MJ, respectively, due to the strict use of natural resources (acorns and grass) during the fattening period. As Iberian farms had a greater dependence on compound feed in *cebo campo*, environmental impacts on CC, AC, EU and CED were 22, 17, 95 and 28% higher, respectively, than with *montanera*. For land occupation (LO), however, *cebo campo* had a lower impact (31.6 m^2·year) than *montanera* (43.0 m^2·year) system. Traditional Iberian pig production systems have environmental impacts higher than conventional systems studied in literature but are similar to other traditional systems. Based on the present assessment, it is necessary to account for the contribution of emissions resulting from the consumption of natural resources to avoid the underestimation of environmental impacts.

Keywords: extensive pig production, environmental impacts, natural resources, local breed.

1. Introduction

Environmental impacts derived from livestock production have received increasing attention in recent times (de Vries & de Boer, 2010), with pig production being one of the main contributors (Steinfeld & Gerber, 2010). However, extensive systems generate a lower level of pollution than other livestock systems (Eldesouky et al., 2018). Many studies estimated the level of these impacts for conventional pig production through Life Cycle Assessment (LCA), which is the most recognized methodology to do so (McAuliffe et al., 2016). One of the main outcomes was that feed production was the main contributor to most of the main environmental impacts investigated, i.e., climate change, energy demand and land occupation (Nguyen et al., 2012; Van Der Werf et al., 2005).

Recent studies focusing on alternative systems, such as organic (Basset-Mens et al., 2007; Dourmad et al., 2014; Halberg et al., 2010; Rudolph et al., 2018) or traditional pig production (Bava et al., 2017; Pirlo et al., 2016) highlighted that such systems usually have higher impacts than conventional ones. Indeed, they use more compound feeds than conventional systems and fatten pigs to a heavier live weight of elder pigs at slaughter. However, few studies suggested that lower impacts may be achieved by outdoor traditional productions with local breeds (Espagnol & Demartini, 2014; Garcia-Launay et al., 2016; Monteiro et al., 2019), given that they strongly rely on the consumption of natural resources available on grasslands and rangelands (e.g., acorns, chestnuts, grass).

In the Southwest of Spain, Iberian pig is an autochthonous breed raised in the ecosystem called *dehesa*. *Dehesa* is defined as open oak forests with ground cover of herbaceous species and sparse shrubs (Rodríguez-Estévez et al., 2009). Extensive production and the use of natural resources by Iberian pigs in *dehesa* generate high quality foods, mainly dry-cured meat products (Benito et al., 2006). Consumer's perception of this livestock production system (pigs raised outdoors) is positive when compared to conventional systems (Argemí-Armengol et al., 2019). The use of natural resources may be exclusive (*montanera*) or partial (*cebo campo*) during the fattening period. We hypothesized that pig production systems highly relying on natural resources like traditional Iberian system with fattening in *montanera* presented lower environmental impacts than systems like *cebo campo* that depend more on compound feeds.

Therefore, the first objective of this study was to evaluate the environmental impacts of traditional Iberian systems, while accounting for the contribution of emissions resulting from the consumption of natural resources (acorns and grass). The second objective was to quantify the reduction of environmental impacts when relying on natural resources and to determine if Iberian pig systems with *montanera* can result in similar impacts to those of conventional systems (per kg of live weight). For these purposes, LCA of traditional Iberian systems was conducted, with two case studies on farms with *montanera* (fattening exclusively with natural resources) and farms with both *montanera* and *cebo campo* systems (*cebo campo* with provision of compound feed for finishing).

2. Materials and Methods

2.1. Description of the System

The system considered is the traditional production of Iberian pigs in the Southwest of Spain, relying on the *dehesa* ecosystem for the finishing period. *Dehesa* is defined as an ecosystem where the surface is occupied by pasture and *Quercus* open woodlands. This ecosystem combines livestock, agricultural and forestry resources. Approximately, *dehesa* produces 1.23 million Iberian pigs per year (RIBER, 2020). The system is characterized by the use of Iberian pure sows and either Iberian pure, Iberian crossbred or Duroc boars. At the breeding season, dry sows and gilts are kept into management corrals that contain one or several boars for a given period (minimum 25 days). Artificial insemination is being used in several farms. After this period, the sows are kept in groups outdoors, consuming rangeland resources. The breeding animals are supplemented with concentrate or by-products depending on the available rangeland resources and their productive state (Benito et al., 2006). The farrowing management is not generally a standard operating practice. The farrowing sows can stay either in traditional huts with outdoor access (sows can eat natural resources) or in farrowing crates (Real Decreto 1135/2002). This breed weans 7.26 piglets per litter and farrows 2.4

times per year in intensive systems (BDporc, 2017). With the traditional production, the number of weaned piglets is 6.38 per litter and the sows farrow twice a year (Duarte et al., 2013). According to the month of birth, the piglets are managed differently (**Figure 1**). Animals born in autumn are intended for *montanera* while animals born in spring are sold as weaned piglets or destined for *cebo campo*. Piglets are weaned at 7–8 weeks in traditional systems, compared to 3–4 weeks in intensive management conditions. The animals are classified as piglets until 23 kg of live weight. Then, Iberian pig production can have two different purposes: piglet production or weaning to slaughtering. If the piglets stay on the farm, the next phase is the growing period where the animals reach 100 kg of live weight in approximately one year (Benito et al., 2006). In this phase, the growing pigs are kept on large areas of rangeland or small outdoor pens where they are supplied with compound feed and have access to rangeland resources. There are two different fattening phases, *montanera* and *cebo campo*, corresponding to different periods of the year (**Figure 1**). The minimum duration required for the fattening phase is 60 days and the pigs are slaughtered at 165 kg of average live weight. In *montanera*, fatteners consume only grass and acorns from October to March. The surface per animal ranges from 0.8 to 4 ha depending on the density of the forested area. In *cebo campo*, the finishing pigs are fed with pasture and compound feed. Animals are kept outdoor on 1 ha for 15 Iberian pigs (Real Decreto 4/2014). Over half of Iberian pigs' production is fattened in *montanera* (51.89%), while the rest (48.11%) is fattened in *cebo campo*. Half of the pigs in *montanera* are Iberian pure (47%), whereas Iberian crossbred represents the mainstream genetics (91%) in *cebo campo* (RIBER, 2020).

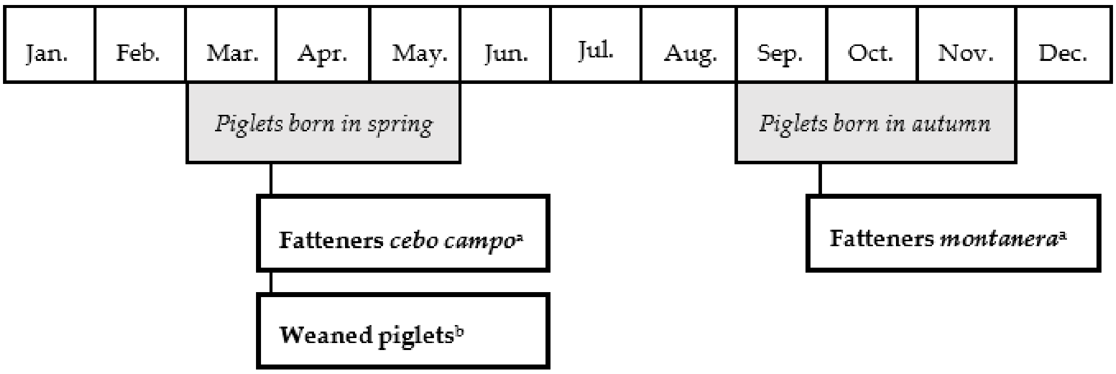


Figure 1. Calendar of traditional Iberian pig production with the extensive system. Destination of piglets according to the season of birth. [a] Fattening the next year; [b] Sale after weaning.

2.2. Goal and Scope Definition

The aim of this study was to conduct an environmental assessment of Iberian pig production systems in *dehesa* through LCA. As in most LCA studies (Dourmad et al., 2014; McAuliffe et al., 2016; Nguyen et al., 2012; Pirlo et al., 2016; Rudolph et al., 2018), environmental impacts were estimated using models, emission factors, and databases previously developed, without direct measurement of emissions. The definition of the system boundaries was derived from Garcia-Launay et al. (Garcia-Launay et al., 2014) and Espagnol and Demartini (Espagnol & Demartini, 2014). The perimeter of the analysis included inputs for crop production, concentrate feed production at the feed factory, animal production unit, and manure storage (**Figure 2**).

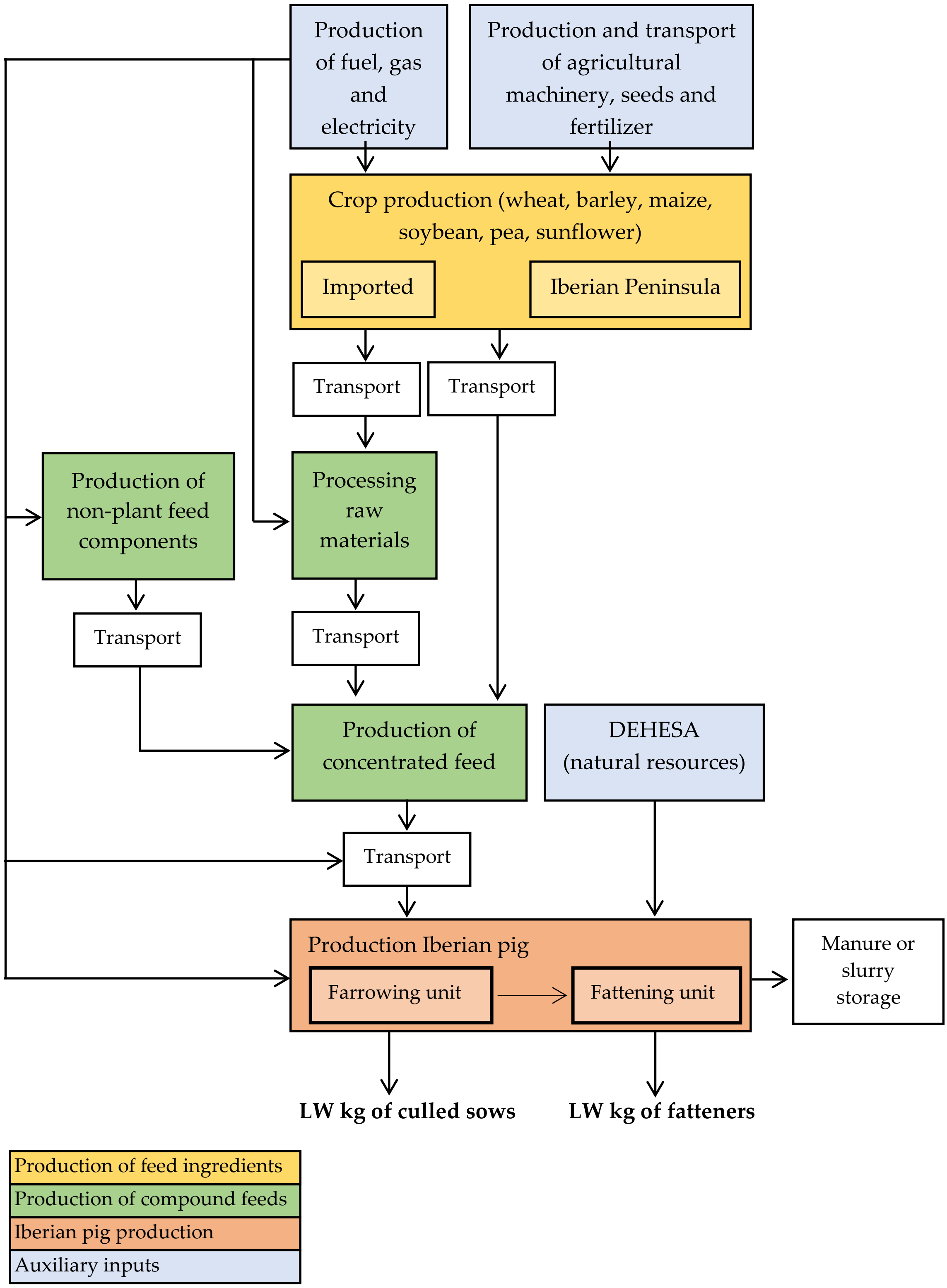


Figure 2. Flow diagram for Iberian pig production in the Southwest of Spain, with the main processes for the production of crop inputs, crop production, production of feed ingredients and feeds and pig production. System boundaries include all sub-processes.

The emissions that occur from nutrients' excretion were considered as well. The LCA considered both crop production in Spain and in other countries. Additionally, the assessment included processing feed ingredients such as soybean meal and sunflower oil and production of industrial products (fat, salt, dicalcium phosphate, calcium carbonate, L-lysine, L-threonine, L-valine and DL-methionine). The systems evaluated were farrow-to-finish systems that fatten all the piglets produced on the farm, in order to evaluate potential impacts of the system rather than impacts directly related to the orientation of the system (i.e., piglet production or production of fattening pigs). Therefore, the functional unit was one kilogram (kg) of live weight (LW) at farm gate (including kg of LW from fattening pigs and culled sows).

Energy use in the building and resources used for the construction of buildings were not included because all animals were raised outdoors except for sows kept in farrowing crates for a few farms (n = 10). Veterinary and cleaning products were also excluded because of lack of data from the surveys.

2.3. Allocation of Impacts

When a production process generates multiple final co-products, it is necessary to allocate the process's impacts to the co-products. For the feed ingredients, allocation of impacts between co-products of cereals and between oils and meals were calculated using economic allocation according to Wilfart et al. (2016). The pig production itself generates fattened pigs of high market value and culled sows. Since the perimeter of the study was farm gate, we did not consider separately the relative products obtained from the different types of animals (fattened pigs and sows).

2.4. Data Acquisition

Data were collected from 33 farms (27 farms of *montanera* fatteners and 6 farms both *montanera* and *cebo campo* fatteners) through questionnaires. Information was collected about farm area (hectares of *dehesa*), number of breeding animals (sows, boars, gilts), number of animals produced and raised (piglets, growers and fatteners), reproductive performance (fertility, born alive and weaned), productive (age and weight at different stages, mortality rates) and management data (amount of feed distributed by type of animal per day, animal housing, etc.).

Farms included in the dataset used either the traditional (outdoor) or the conventional (indoor) farrowing system, and produced either pure Iberian or a part of crossbred pigs (50% up to 75% Iberian).

Feed composition was collected from two feed companies for all physiological stages (sows gestation, sows lactation, piglets, weaners, growers and *cebo campo* fatteners). The main feed ingredients used were maize, barley, soft wheat, spring pea, soybean meal and sunflower oil (for more details see **Table S1** in supplementary material).

2.5. Life Cycle Inventories for Feed Ingredients

For feed ingredients related to crop production in Spain (soft wheat, maize, barley, spring pea and sunflower), life cycle inventories were derived from the ones constructed for the same crops in France by Wilfart et al. (2016). The yield and irrigation levels were modified according to data from the Spanish Ministry of Agriculture, Fishery and Food (MAPA, 2019). Amounts of mineral fertilizers were specified according to national recommendations (García-Serrano et al., 2009), emissions of $N\text{-}N_2O$, $N\text{-}NO_3$ and NO_X were calculated according to IPCC (2006) and emission of $N\text{-}NH_3$ was calculated according to SEI (2012). For soybean from Brazil, the life cycle inventory was taken from Wilfart et al. (2016). The electricity mix was modified for the Spanish electricity mix.

Distances for transportation of crops in Spain were calculated according to data from the Spanish Ministry of Agriculture, Fishery and Food (MAPA, 2019) considering the distances from different regions of crop production in Spain (Andalucia, Aragon, Extremadura, Castilla-Leon, Castilla-La Mancha and Catalonia) to the Iberian pig region (Andalucia and Extremadura). The transport of feed ingredients to feed factory was considered in trucks with distances depending on the raw material (soft wheat at 344 km, maize at 277 km, barley at 375 km, spring pea at 371 km and sunflower at 340 km). Overseas transportation of soybean from Brazil to Europe was considered with soybean arrival at Lisbon harbour (7500 km) and transportation up to the Iberian pig region by trucks (300 km) for crushing.

2.6. Life Cycle Inventories for Pig Production

Life cycle inventories of feeds were constructed using the incorporation rates of each feedstuff found in the feed formulas provided by feed manufacturers. Transportation of feeds to the farms was added from data provided in the questionnaires (58.60 ± 72.89 km). Feed intake per type of animal (gestating sow, lactating sow, grower, fattener) was calculated from information provided by a representative sample of Iberian pig farmers (**Table 1**).

Table 1. Consumption of feed and natural resources according to type of animal (n = 33 farms).

	Amount (Kg DM)	Minimum Value	Maximum Value
Sow			
Intake gestation feed (/year)	455.9 ± 167.1	152.5	1068
Intake lactation feed (/year)	264.7 ± 86.28	145.5	523.8
Grass intake [a] (/year)	106.0 ± 9.64	71.27	121.4
Piglets-weaners			
Feed intake (/piglet)	2.91 ± 1.37	1.15	7.40
Growers			
Feed intake (/pig)	405.3 ± 26.29	360.0	468.0
Grass intake [a] (/pig)	161.6 ± 14.60	126.8	186.8
Fatteners cebo campo			
Feed intake (/pig)	563.3 ± 37.70	428.1	608.3
Grass intake [a] (/pig)	34.85 ± 3.18	30.87	40.32
Fatteners montanera			
Acorn intake [b] (/pig)	271.6 ± 36.66	217.5	348.0
Grass intake [b] (/pig)	46.82 ± 6.32	37.50	60.00

[a] Grass intake is calculated according to literature and feed intake; [b] Acorn and grass intake in fatteners montanera is calculated according to literature and fattening period (days); DM: Dry Matter.

Grass intake was calculated for sows outdoors (Rivera Ferre et al., 2001). Furthermore, grass intake of growers and fatteners *cebo campo* was estimated as a function of compound feed supply according to Monteiro et al. (2019). In both cases, the summer months were not included in the estimation of grass intake due to the null grass growth in the South West of the Iberian Peninsula during this season (Olea et al., 1990).

Similarly, acorn and grass intakes in fatteners *montanera* were estimated through literature data (Rodríguez-Estévez et al., 2010, 2011) and average time spent in *montanera* indicated in questionnaires (**Table 1**).

Excretion of N, P, organic matter (OM) and digested fibre were calculated by a mass-balance approach. N, P, OM and digested fibre intakes were calculated from feed, grass and acorn intakes and the nutrient contents of each one. Nutrient contents of feeds were provided by feed manufacturers. Nutrient contents of grass and acorn were consulted in literature (FEDNA, 2018; García-Valverde et al., 2007; Vázquez et al., 2008). For N and P, body retention was calculated according to Rigolot et al. (2010a) considering a lean percentage at slaughter of 30% from Freitas (1998) for N, and according to Dourmad et al. (2015) for P. Excretion was calculated for each physiological stage as the difference between nutrient intake and nutrient retention. Excretion of OM resulted from OM intake and digestibility of OM (García-Valverde et al., 2007, 2010).

Emissions of NH_3, N_2O, NO_X, NO_3 and CH_4 were calculated independently for gestating sows, lactating sows, weaners, growers, fatteners *cebo campo* and fatteners *montanera*. For animals kept outdoors, the emissions of N-NH_3, N-N_2O, N-NO_x and N-NO_3 were estimated according to the emission factors proposed by Basset-Mens et al. (2007). In addition, the emissions for indoor farrowing sows of N-NH_3, N-N_2O, N-NO_x (Rigolot et al., 2010b) and N-NO_3 (Garcia-Launay et al., 2014) were calculated. Emissions of CH_4 produced by enteric fermentation and manure management were estimated using Rigolot et al. (Rigolot et al., 2010a, 2010b) and IPCC (2006).

2.7. Characterization of the Impacts

We calculated the impacts of Iberian pig production on climate change ILCD (CC, kg CO_2 eq), acidification ILCD (AC, molc H^+ eq), eutrophication CML baseline (EU, kg PO_4^{3-} eq), cumulative energy demand V1.8 non-renewable fossil+nuclear (CED, MJ) and land occupation CML non baseline (LO, m^2·year). We used the International Reference Life Cycle Data System (ILCD) characterisation method recommended by the Joint Research Centre (2012) for CC and AC, as well as the CML-IA characterisation method (SimaPro, 2015), which is the most popular in agricultural LCA. Energy demand was calculated according to the CED 1.08 method (SimaPro, 2015). Analyses were performed with Simapro software (version 8.5.2.0, PRé Consultants, Amersfoort, The Netherlands) and the ecoinvent v3.1 database for background data (2013) related to transportation and electricity production.

3. Results

3.1. Iberian Pig Performance

Productive indicators of Iberian pig farms varied greatly in the dataset. The average farm surface was 670 ± 636.2 ha where 529 ± 437.8 ha were used in the *montanera* period. Farms had an average of 34.4 ± 25.23 sows with 2 farrowing per year and 4 ± 3.79 boars. The number of weaned piglets was 6.17 ± 0.74 per litter with 11.6 ± 4.40 kg of mean weight and 45.3 ± 12.91 days at weaning (depending on the management of farrowing). The average production per farm was 213.8 ± 141.29 fatteners *montanera* per year with 178.7 ± 11.23 kg of mean slaughter weight and stocking density between 0.2 and 1.11 pigs/ha (in compliance with Real Decreto 4/2014) with an average density of 0.57

fatteners/ha. In farms with two types of fattening, 213 fatteners *cebo campo*, on average, were produced per year (for more details see **Table S2** in supplementary material).

3.2. Impacts of Feed Ingredients and Complete Feed

Environmental impacts of production and delivery at the feed factory of 1 ton of each feed ingredient is shown in **Table 2**. Maize had the lowest value for CC. Barley, spring pea and wheat showed intermediate values for this impact. Soybean meal from Brazil and sunflower oil had the highest values for CC. For AC, the value of sunflower oil was twice higher compared to maize and the values of the other feed ingredients were lower. EU impact of sunflower oil obtained also the highest value (19.89 kg PO_4^{3-} eq) while other feed ingredients had values from 4 to 8 kg PO_4^{3-} eq. The highest values for CED were for sunflower oil, the intermediate values for spring peas and soybean meal and the lowest values for cereals (wheat, barley and maize). For LO, sunflower oil (17667 m^2·year) presented the highest values and the other feed ingredients had values lower than 10000 m^2·year/ton. Sunflower oil was only used in fattening feed.

Table 2. Environmental impacts due to the production and delivery of 1 ton of each feed ingredient (at feed factory gate).

Feed Ingredients	CC	AC	EU	CED	LO
	kg CO_2 eq	molc H^+ eq	kg PO_4^{3-} eq	MJ	m^2·year
Barley Spain	633.8	7.92	6.41	4777	2917
Maize Spain	385.4	10.74	5.04	3281	907
Soybean meal Brazil	1124.4	7.18	4.84	7846	1529
Spring pea Spain	702.4	7.91	5.47	9635	9441
Sunflower oil Spain	1988.7	21.56	19.89	20,180	17,767
Wheat Spain	705.5	8.88	7.24	5213	2996

Climate Change (CC), Acidification (AC), Eutrophication (EU), Cumulative energy demand (CED), Land occupation (LO).

Environmental impacts of the different compound feeds were similar within a same production stage (**Table 3**). In sow feeds, lactation feed showed higher values than gestating feed except for LO (2303 m^2·year/ton). Meanwhile, the impact values of transition feed were higher than the values in starter feed for weaned piglets except for AC (10.02 molc H^+ eq/ton). For growing feed, AC and EU were higher (9.37 molc H^+ eq/ton and 7.04 kg PO_4^{3-} eq/ton, respectively) for company 1, and CC, CED and LO were higher (808.5 kg CO_2 eq/ton, 7321 MJ and 3060 m^2·year/ton, respectively) for company 2. In the fattening stage, the compound feeds of company 2 (*fattening 2* and *quality fattening*) showed higher values compared to feeds of company 1 (*fattening 1* and *final fattening*). *Quality fattening* feed presented the highest values among the feeds provided for fatteners.

3.3. Impacts of Iberian Pig Production in Dehesa

Table 4 shows the average environmental impacts for Iberian pig production, for farms finishing pigs in *montanera*, and for farms with pigs finished in either *montanera* or *cebo campo*. Farms with fatteners from *montanera* and fatteners from *cebo campo* exhibited values of CC (4.36 kg CO_2), AC (0.110 molc H^+), EU (0.057 kg PO_4^{-3}) and CED (28.6 MJ) per kg of pig 22, 17, 95 and 28% higher, respectively, than farms with fatteners only in *montanera*. For LO, however, values per kg of pig were higher for farms using only *montanera* fattening (43.0 m^2·year) than for farms using both *montanera* and *cebo campo* (31.6 m^2·year).

Table 3. Environmental impacts due to the production at the feed factory gate of 1 ton of each compound feed.

Compound Feed	CC kg CO_2 eq	AC molc H^+ eq	EU kg PO_4^{3-} eq	CED MJ	LO m^2·year
Sow					
Gestating	764.3	9.06	6.83	6682	2598
Lactating	805.0	9.55	6.88	7087	2303
Piglets-weaners					
Starter	768.1	10.25	7.20	7296	1886
Transition	812.2	10.02	8.07	7634	2187
Growers					
Growing1 [a]	773.0	9.37	7.04	6835	2396
Growing2 [a]	808.5	8.98	6.85	7321	3060
Fatteners cebo campo					
Fattening1 [a]	695.5	9.55	6.47	6191	2396
Fattening2 [a]	774.9	9.58	7.07	7420	3386
Final Fattening	686.2	9.66	6.58	6143	2445
Quality Fattening	818.9	9.88	7.66	7997	4486

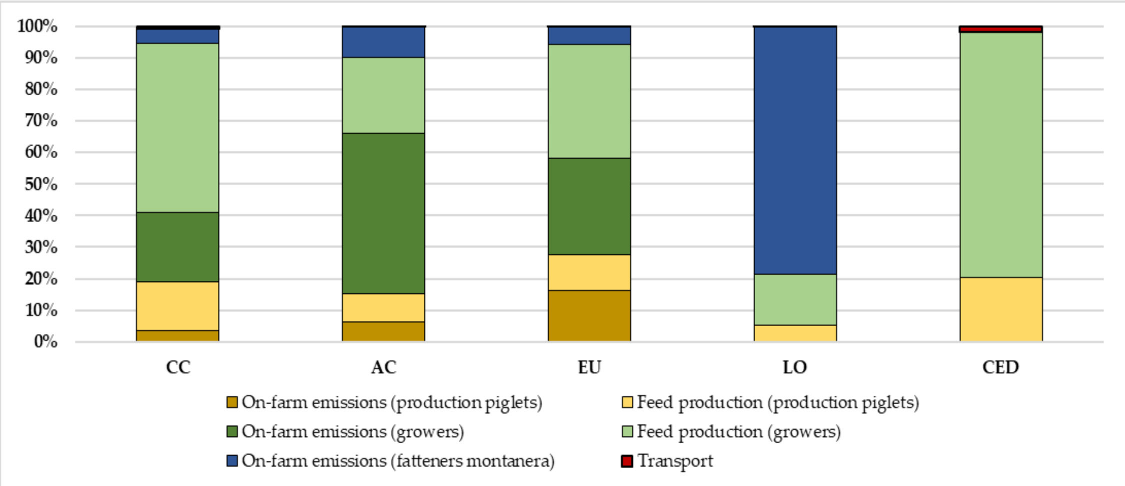
Climate Change (CC), Acidification (AC), Eutrophication (EU), Cumulative energy demand (CED), Land occupation (LO); [a] Environmental impacts of feed 1 and feed 2 refer to the impacts calculated for the feed produced by Company 1 and the feed produced by Company 2, respectively.

Table 4. Environmental impacts of pig production in the traditional Iberian system, obtained from the whole dataset (33 farms).

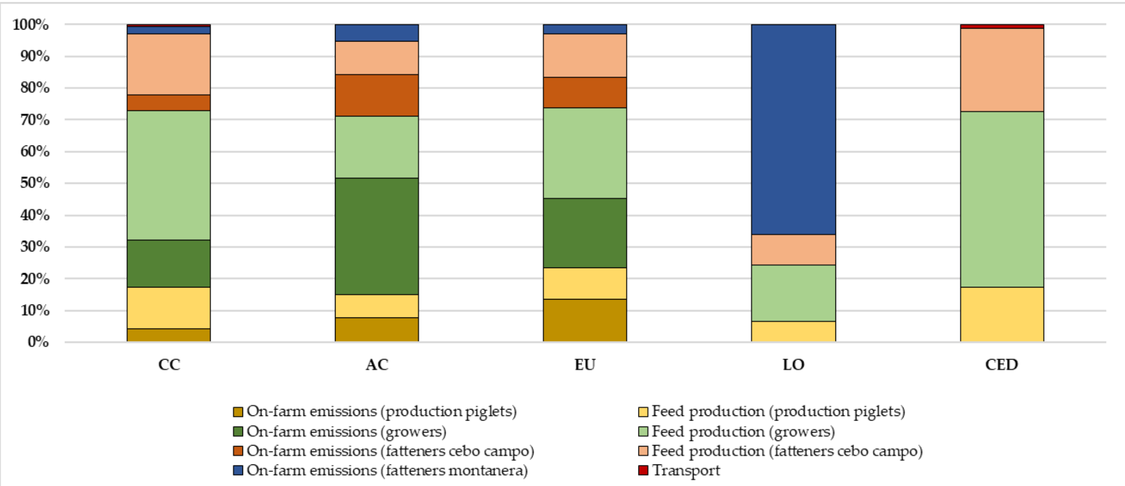
Environmental Impacts	Mean ± Standard Deviation	Minimum Value	Maximum Value
Impacts Per kg of Live Pig at Farm Gate in Farms with *montanera* (27 Farms)			
Climate change (kg CO_2 eq)	3.40 ± 0.223	2.88	3.84
Acidification (molc H+ eq)	0.091 ± 0.004	0.08	0.10
Eutrophication (kg PO_4^{3-} eq)	0.046 ± 0.002	0.04	0.05
Non-renewable Energy (MJ)	20.65 ± 1.698	16.78	23.36
Land Occupation (m^2·year)	43.01 ± 22.807	16.46	126.0
Impacts Per Kg of Live Pig at Farm Gate in Farms with *montanera* and *cebo campo* (6 Farms)			
Environmental Impacts	**Mean ± Standard Deviation**	**Minimum Value**	**Maximum Value**
Climate change (kg CO_2 eq)	4.36 ± 0.428	3.90	5.16
Acidification (molc H+ eq)	0.110 ± 0.010	0.10	0.13
Eutrophication (kg PO_4^{3-} eq)	0.057 ± 0.005	0.05	0.07
Non-renewable Energy (MJ)	28.57 ± 3.523	24.09	34.81
Land Occupation (m^2·year)	31.60 ± 6.662	24.17	42.65

3.4. Contribution of Processes to Impacts

Figure 3a shows the contribution of the different stages of Iberian pig production to environmental impacts in the farms with animals fattened only in *montanera*. Growing stage showed the greatest contribution to CC, AC, EU and CED whereas the finishing period contributed to LO the most. The impacts of the growing period and of the production of piglets were caused by both on-farm emissions and feed production, whereas feed production for finishing pigs did not contribute to the impacts since no feed was supplied for fattening in *montanera*. Contribution of transport was low in all environmental impacts (between 0-2%).



(**a**)



(**b**)

Figure 3. Mean contribution of physiological stages (production of piglets, growers, fatteners) and transport to climate change (CC), acidification (AC), eutrophication (EU), cumulative energy demand (CED) and land occupation (LO) impacts expressed per kg of pig live weight at farm gate. (**a**) Farms fattening all pigs in *montanera* (27 farms) and (**b**) Farms fattening some pigs in *montanera* and some pigs in *cebo campo* (6 farms).

The growing stage was the greatest contributor to CC (75%) followed by the production of piglets (19%). Feed production was the main contributor to CC of these production stages (53% in growers and 15% in production of piglets). Fatteners' contribution to CC (5%) was only associated with on-farm emissions. Growing period was responsible for 75% of the AC potential impact, mainly with on-farm emissions (51%). Piglets production contributed to 15% of AC (9% feed production and 6% on-farm emissions). On-farm emissions associated with finishing pigs accounted for 10% of AC. EU followed the same ranking of production stages as previous impacts. First, growers contributed to 66% and secondly, production piglets contributed to 27% of impacts. In this case, feed production and on-farms emissions had a similar contribution to the EU, in the growing stage (36% and 30%, respectively) and in the production of piglets (16% and 11%, respectively). Finishing pigs showed a low contribution (6%) to EU, from on-farm emissions. CED impact resulted only from feed production and transport, 78% due to the growing stage and 20% due to the production of piglets. LO impact was mainly determined by fatteners in *montanera* (79%), followed by growers and production piglets (16% and 5%, respectively).

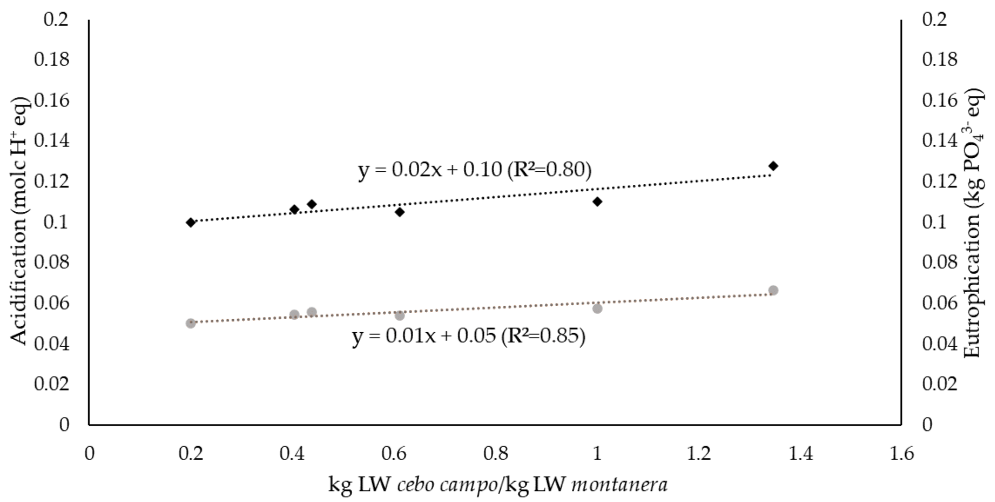
When the farms fatten animals in *montanera* and *cebo campo* the contribution of the different stages to environmental impacts had a different pattern (**Figure 3b**). In this farm type, contribution of transport was also low in all environmental impacts (between 0 and 1 per cent). Main production stages contributing to impacts (CC, AC, EU and CED) were growers, fatteners in *cebo campo*, production piglets and fatteners in *montanera*. The main production stage contributing to LO impact was fatteners in *montanera*.

For CC, AC and EU impacts, growing pigs resulted in more than half of the emissions (55%, 56% and 50%, respectively). Fatteners in *cebo campo* caused about a quarter of emissions (24%, 23% and 23%, one by one). The production of piglets had a lower contribution to these impacts (17%, 15% and 23%, respectively). Feed production was less important than on-farm emissions in AC. Fatteners in *montanera* only produced on-farm emissions (2% in CC, 5% in AC and 3% in EU). CED impact was determined by the production of feed for growers, fatteners *cebo campo* and the production of piglets (55%, 26% and 17%, respectively). Finally, LO impact was mainly determined by fatteners in *montanera* (66%), followed by growers, fatteners *cebo campo* and production of piglets (18%, 9% and 7%, respectively).

3.5. Relationship Between Type of Fattening System and Environmental Impacts

Six farms of the dataset produced two types of fatteners (*montanera* and *cebo campo*). **Figure 4** shows the relationships between the ratio of production from *cebo campo* (kg of LW) to production from *montanera* (kg of LW) (ProdRatio) and the different environmental impacts.

a)



b)

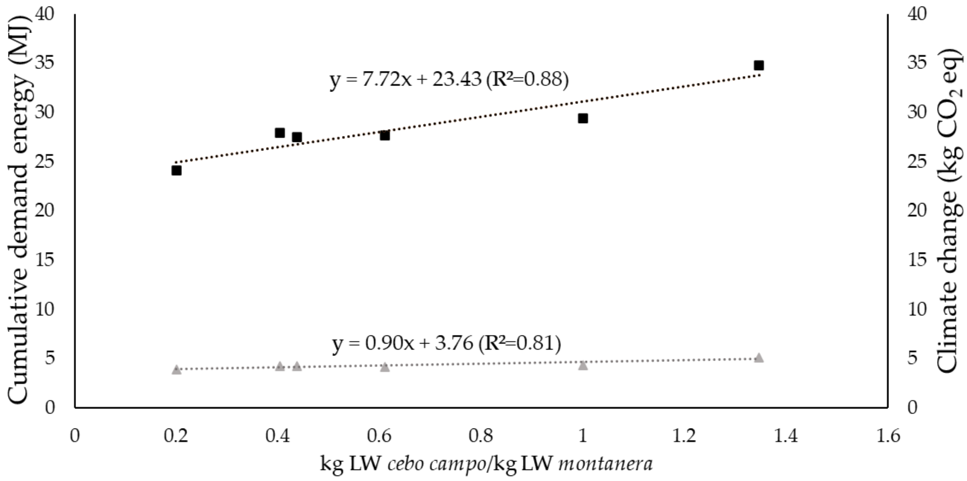


Figure 4. Potential environmental impacts of pig production. (**a**) acidification (♦) and eutrophication (●), (**b**) cumulative demand energy (■) and climate change (▲) according to the type of fattening expressed as the ratio between the production made in *cebo campo* system and the production made in the *montanera* system. The kilogram of live weight (LW) is plotted on the x-axis.

The higher the ratio, the greater the impact was, for CC, AC, EU and CED. The relationship between LO impact and ProdRatio was less clear ($R^2 = 0.57$) since the area dedicated to outdoor pigs in each farm was very variable.

4. Discussion

4.1. Methodological Challenge: Accounting for the Consumption of Natural Resources

The present study is one of the first to include the emissions resulting from the consumption of natural resources in the assessment. In traditional Iberian systems, the excretion of nutrients associated with the consumption of natural resources contributes to CC, AC, EU and LO impacts. This contribution applies to the different outdoor stages. For CC, AC and EU the contribution of natural resources corresponded to on-farm emissions of fatteners *montanera* and to one part of the on-farm emissions of the other outdoor stages (sows, growers and fatteners *cebo campo*). For LO, the contribution of natural resources was associated to both the surface of *dehesa* occupied by fatteners *montanera* during approximately 100 days and the surface of grasslands used for the other outdoor stages (sows, growers and fatteners *cebo campo*).

In systems depending on the consumption of natural resources by outdoor pigs, like the traditional Iberian production system, it appeared relevant to consider the acorn and grass intakes in the life cycle perimeter. Indeed, the contribution of fatteners *montanera* reached at least 5% of CC, 6% of EU and 10% of AC (**Figure 3a**). The final contribution of the consumption of natural resources was higher because there was also contribution from the other outdoor production stages. The fatteners *montanera* accounted for at least 79% of LO (**Figure 3a**) because of the large surfaces used (between 0.2 and 1.11 pigs per hectare).

When Iberian farms have both *montanera* and *cebo campo* systems, the contribution of natural resources to impacts decreases due to greater dependence on compound feed. In these farms, the contribution of fatteners *montanera* (depended on natural resources) was reduced to half for CC, AC and EU impacts in comparison with farms with only fatteners *montanera* but remained predominant in LO impact (**Figure 3b**).

Depending on the type of natural resource consumed by pigs during each productive stage, the emissions may vary. Consumption of acorns should result in low emissions due to their low N and digestible fibre content and high OM digestibility (García-Valverde et al., 2007). Consumption of grass should have higher contribution to emissions, because of its higher digestible fibre and crude protein content, i.e., 22.20% of CP compared to 5.88% of CP for acorn (García-Valverde et al., 2007). Therefore, when animals consume grass, higher N excretion and emissions of NH_3, NO_X and NO_3 are expected. Additionally, because of its higher digestible fibre content, higher enteric CH_4 emissions are expected (Rigolot et al., 2010a, 2010b). Grazing by the animals is related to enteric fermentation (Eldesouky et al., 2018). Therefore, it was relevant to account for natural resources in the LCA of the Iberian traditional pig production system, since these resources are consumed during all production stages. Indeed, although *dehesa* can be considered a natural ecosystem without intervention from farmers, N and OM ingested from acorns and grass are provided to the environment in a form (urine and faeces) that is expected to result in higher volatilization than natural degradation on the ground. Therefore, we have recommended the inclusion of emissions derived from the consumption of natural resources in the perimeter of an LCA when dealing with systems with outdoor pigs, because it contributes to about 10% of CC, AC and EU.

If the intake of natural resources had not been included in the assessment (**Table 5**), no emissions of NH_3, N_2O, NO_X, NO_3, CH_4 would have been considered in fatteners during *montanera*. Additionally, emissions estimated of NH_3, N_2O, NO_X, NO_3 would have decreased by 40% in growing pigs. In the case of fatteners *cebo campo*, the decrease in these emissions would have represented only 10%, due to a higher intake of compound feed per day and a decrease in grass intake (Monteiro et al., 2019).

Table 5. Average emissions of nitrogen compounds and methane per pig, when accounting or not for excretion of nutrients resulting from the consumption of natural resources (grass and acorn).

Production Stage	NH_3 (Kg)	N_2O (Kg)	NOx (Kg)	NO_3 (Kg)	CH_4e (Kg)	CH_4m (Kg)
Growers						
NR considered	2.62	0.283	0.092	22.30	1.478	0.332
NR not considered	1.56	0.168	0.055	13.30	0.407	0.276
Emission reduction [a] (%)	40.37				72.49	16.86
Fatteners cebo campo						
NR considered	2.15	0.232	0.076	18.30	0.728	0.438
NR not considered	1.94	0.209	0.068	16.47	0.508	0.427
Emission reduction [a] (%)	10.00				30.28	2.65
Fatteners montanera						
NR considered	0.523	0.056	0.018	4.45	0.403	0.111
NR not considered	0.000	0.000	0.000	0.00	0.000	0.000
Emission reduction [a] (%)	100.0					

[a] Emission reduction if natural resources are not included in the LCA perimeter; NR: natural resources; CH_4e: CH_4 enteric; CH_4m: CH_4 from manure.

Furthermore, the emissions calculated of enteric CH_4 and CH_4 from the faeces and urine deposited would have also decreased in these production stages. The reduction of emissions in sows was not calculated since lactating sows have access to natural resources only in some farms (farrowing in huts). Consumption of natural resources was not considered for piglets, because of the post-natal development of the digestive system (Barszcz & Skomiał, 2011).

4.2. Environmental Impacts of Iberian Traditional Pig Production Systems vs. Other Pig Production Systems

This study provided the first life cycle assessment of traditional Iberian pig production. Several authors estimated environmental impacts of pig production (**Table 6**). Conventional, organic and traditional systems have already been assessed through LCA (McAuliffe et al., 2016). Therefore, in this section we compare the environmental impacts of pig production in traditional Iberian systems with conventional, organic and traditional systems investigated in the literature. We also provide insights on the potential mitigation of impacts through the consumption of natural resources by free-ranging pigs.

In Iberian pig production systems, CC, AC, EU and LO values (**Table 4**) are higher than those obtained in conventional systems (**Table 6**). Indeed, conventional systems are commonly based on high productivity, while extensive systems promote carcass quality over quantity (De Miguel et al., 2015). CC in conventional systems ranges between 2.22 and 2.89 kg CO_2 eq (Basset-Mens & Van Der Werf, 2005; Dourmad et al., 2014; Garcia-Launay et al., 2014; González-García et al., 2015; Mackenzie et al., 2016; Monteiro et al., 2016; Pelletier et al., 2010) while EU ranges between 0.014 and 0.023 kg PO_4^{3-} eq (Basset-Mens & Van Der Werf, 2005; Dourmad et al., 2014; Garcia-Launay et al., 2014; Mackenzie et al., 2016; Pelletier et al., 2010) and AC between 0.058 and 0.063 molc H^+ (Wilfart et al., 2019). Iberian pig systems had higher CC, AC and EU impacts than conventional systems, in both farms with only fatteners *montanera* (3.40 kg CO_2, 0.091 molc H^+ and 0.046 kg PO_4^{3-} eq, respectively) and farms with fatteners *montanera* and *cebo campo* (4.36 kg CO_2, 0.110 molc H^+ and 0.057 kg PO_4^{3-} eq, respectively). This was due to the lower feed efficiency of the traditional breeds (Muñoz et al., 2018). LO in this study (31.60 and 43.01 $m^2 \cdot$year) was lower than LO in a conventional system reported in the literature (Basset-Mens & Van Der Werf, 2005; Dourmad et al., 2014; Monteiro et al., 2016). It resulted from land surfaces required for fatteners *montanera* (Real Decreto 4/2014). CED in Iberian farms with fatteners *montanera* and *cebo campo* (31.60 MJ) was higher than CED in conventional production, due to large quantities of compound feed distributed during growing and finishing periods to fatteners of *cebo campo*. However, CED in Iberian farms using only *montanera* (20.65 MJ) is approximately equivalent to the highest values (16.22 and 20.80 MJ) in conventional systems (Dourmad et al., 2014; Garcia-Launay et al., 2014). Environmental impacts of Iberian pig production in traditional systems are reduced when using only the *montanera* system for finishing (vs. *cebo campo*). Therefore, relying on the ability of Iberian pigs to consume acorns and to valorise them with compensatory growth allows these systems to reach environmental impacts close to those of conventional systems despite lower growth potential.

Table 6. Results of CC, EU, CED and LO of conventional, organic and traditional systems from recent LCA studies.

Reference	Country	System	Mgmt	CC	EU	CED	LO
				(kg CO_2 eq)	(kg PO_4^{3-} eq)	(MJ)	(m^2·year)
Basset-Mens et al. (2005)	FR	C	I	2.30	0.021	15.90	5.43
Pelletier et al. (2010)	US	C	I	2.47	0.016	9.70	
Garcia-Launay et al. (2014)	FR	C	I	2.22–2.77	0.017–0.023	18.10–20.80	
Dourmad et al. (2014)	UE	C	I	2.25	0.019	16.22	4.13
González-García et al. (2015)	PT	C	I	2.61		14.30	
Monteiro et al. (2016)	FR	C	I	2.28–2.89		11.70–14.40	3.89–4.05
Mackenzie et al. (2016)	CA	C	I	2.24–2.32	0.014	15.80	
Basset-Mens et al. (2005)	FR	O	I/O	3.97	0.022	22.20	9.87
Halberg et al. (2010)	DK	O	I	2.92			6.90
Halberg et al. (2010)	DK	O	O	3.32			9.20
Halberg et al. (2010)	DK	O	I/O	2.83			8.50
Dourmad et al. (2014)	UE	O	O	2.43	0.016	18.08	9.14
Rudolph et al. (2018)	UE	O	I	2.20	0.022		
Rudolph et al. (2018)	UE	O	I/O	2.21	0.020		
Rudolph et al. (2018)	UE	O	O	2.21	0.029		
Dourmad et al. (2014)	UE	T	I/O	3.47	0.034	24.28	10.58
Espagnol & Demartini (2014)	FR	T	O	4.09	0.054	20.20	6.43
Espagnol & Demartini (2014)	FR	T	O	3.03	0.053	15.80	7.83
Espagnol & Demartini (2014)	FR	T	O *	1.47	0.012	7.70	2.14
Pirlo et al. (2016)	IT	T	I	3.30	0.031		
Bava et al. (2017)	IT	T	I	4.25	0.026	23.50	8.39
Garcia-Launay et al. (2018)	FR	T	O	4.54	0.047	19.90	22.70
Monteiro et al. (2019)	SI	T	I/O	6.94	0.038	35.60	10.40
Monteiro et al. (2019)	IT	T	I/O	9.35	0.036	33.70	7.55
Monteiro et al. (2019)	FR	T	I/O	5.07	0.047	24.70	11.00

Mgmt: Management; C: Conventional; O: Organic; T: Traditional; I: Indoor; O: Outdoor; * Dependent exclusively on natural resources in fattening.

Iberian systems have CC, EU and LO impacts (**Table 4**) rather greater than organic systems (**Table 6**), since these systems exhibit CC values between 2.20 and 2.92 kg CO_2^- eq (Dourmad et al., 2014; Halberg et al., 2010; Rudolph et al., 2018), EU values from 0.016 to 0.029 kg PO_4^{3-} eq (Basset-Mens & Van Der Werf, 2005; Dourmad et al., 2014; Halberg et al., 2010) and LO values from 6.9 to 9.87 m^2·year (Basset-Mens & Van Der Werf, 2005; Dourmad et al., 2014; Halberg et al., 2010). Halberg et al. (2010) additionally assessed a free range organic system, and calculated a CC value (3.32 kg CO_2 eq) close to those of Iberian farms with fatteners *montanera* (3.40 kg CO_2^- eq). A long productive cycle with high slaughter weight and a low feed efficiency (Benito et al., 2006; Muñoz et al., 2018) were the main causes of higher impacts in Iberian systems than in organic systems. In contrast, the CED value obtained (**Table 4**) in this study was near the CED value in organic systems (18.08 MJ) (Dourmad et al., 2014) when finishing pigs were fed only with natural resources. In addition, Basset-Mens et al. (2005) obtained higher CC and CED values in the organic system than Iberian farms for fatteners *montanera* but lower than Iberian farms with fatteners *montanera* and *cebo campo*.

In recent years, environmental impacts of traditional pig production were estimated by several authors (Bava et al., 2017; Dourmad et al., 2014; Espagnol & Demartini, 2014; Garcia-Launay et al., 2016; Monteiro et al., 2019; Pirlo et al., 2016)(Bava et al., 2017; Dourmad et al., 2014; Espagnol & Demartini, 2014; Garcia-Launay et al., 2018; Alessandra Nardina Trícia Rigo Monteiro et al., 2019; Pirlo et al., 2016). The values (**Table 6**) vary greatly due to different farm managements and breeds. For this reason, CC, EU and CED impacts in Iberian systems are within the range of values found in the literature (3.03 to 9.35 kg CO^2 eq, 0.026 to 0.054 kg PO_4^{3-} eq and 14.40 and 35.60 MJ, respectively). Traditional indoor systems had lower EU values, while traditional outdoor systems like the Iberian one obtained the highest EU values. Traditional mixed systems (indoor and outdoor) obtained EU intermediate values. Indeed, the higher efficiency of intensive systems needs less inputs per functional unit than extensive systems (Eldesouky et al., 2018). Finally, LO values in Iberian systems are higher than LO values in other traditional systems (6.43 to 22.70 m^2·year) primarily due to the use of a large surface in the fattening period. A traditional Corsican system (Espagnol & Demartini, 2014) obtained the lowest CC, EU, CED and LO values (1.47 kg CO^2 eq, 0.012 kg PO_4^{3-} eq, 7.70 MJ and 2.14 m^2·year, respectively) of the assessed traditional systems.

Consumption of natural resources (chestnuts, acorns and grass) in LCA was only previously considered by Monteiro et al. (2019) who calculated the emissions from grazing in different systems using local breeds. Espagnol and Demartini (2014) did not considered the natural resources in the LCA perimeter when assessing the environmental impacts of Corsican pig production systems. Environmental impacts obtained in traditional Iberian systems (**Table 4**) were in line with the values obtained with other European local breeds (Monteiro et al., 2019). However, values obtained in this study were higher than the ones obtained by Espagnol and Demartini (2014) for the Corsican system.

One of the causes for high impacts in Iberian pig systems is that Iberian pig protein deposition is potentially lower than in modern highly selected breeds (Muñoz et al., 2018). Additionally, the animals reared in free-range use the calories to cover energy requirements for maintenance and the energetic cost of grazing (Rodríguez-Estévez et al., 2010). As a result, the feed efficiency was also lower in this system. The use of natural resources from the *dehesa* (Benito et al., 2006) together with the ability of Iberian pigs to shell acorns (Rodríguez-Estévez et al., 2007) may compensate the lower feed efficiency when animals are fed with natural resources. Indeed, when the ratio of production from *cebo campo* to production from *montanera* increased, the different environmental impacts increased and vice versa (**Figure 4**). This was due to greater use of compound feed in *cebo campo*. Furthermore, a low distribution of compound feed per day during the growing period in Iberian pigs causes compensatory growth in *montanera*, which increases feed efficiency and contributes to reduced N excretion and environmental impacts. According to Stanley et al. (2018), the management of fatteners *montanera* (extensive fattening based on natural resources in a large area with rotational management) provides environmental benefits (such as soil C sequestration and other ecosystem services) and lower environmental impacts per kilogram carcass weight. Therefore, the *montanera* system generates lower total meat production, although it is produced with greater environmental benefits than the *cebo campo* system.

5. Conclusions

This study provides the first life cycle assessment of traditional Iberian pig production. Traditional Iberian pig production has lower climate change, eutrophication, acidification and cumulative energy demand impacts when relying on *montanera* fattening than when relying on *cebo campo* fattening. As a result, land occupation impact is increased with *montanera* fattening due to the use of large surfaces to provide natural resources to the animals. To our knowledge, it addresses for almost the first time the effect of emissions associated with the consumption of natural resources available on pasture and open woodlands on the level of the environmental impacts. The contribution of emissions derived from the consumption of natural resources to climate change, acidification and eutrophication impacts reached about 10%. Therefore, they should be included in the LCA to avoid underestimation of the environmental impacts for systems in which natural resources are used. The greater use of natural resources seems to be an option for reducing the environmental impact of this system, which can reach values close to those obtained for conventional systems. This reduction of environmental impacts is mainly due to a reduction in the consumption of compound feed. Therefore, a better management of natural resources could reduce the dependence on compound feed and could make Iberian traditional pig production more environment-friendly. The traditional Iberian farms are also needed for the conservation of the ecosystem called *dehesa*. The preservation of the *dehesa* ecosystem through the conservation of traditional Iberian systems for the production of high-quality meat products may be achieved at limited environmental impacts through higher reliance on the natural resources provided by the *dehesa* ecosystem.

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Supplementary Material

Table S1: Chemical composition of feed formulas and natural resources and feed ingredients incorporated into each feed formula.

Chemical composition (g/kg)	*Sow*		*Piglets-weaners*		*Growers*		*Fatteners cebo campo*				*Natural resources*	
	Gestating	Lactating	Starter	Transition	Gr [1]	Gr [2]	Fat [1]	Fat [2]	Final Fat	Quality Fat	Acorn	Grass
CP	140.4	173.2	157.5	166.3	154.9	161.4	115.3	157.4	107.9	150.9	58.80	222.0
OM	849.5	851.4	859.3	852.8	849.6	849.0	854.9	851.4	855.2	853.3	978.0	852.0
OMd	661.9	645.6	654.6	657.4	651.1	636.6	653.8	596.93	643.08	601.78	856.7	746.4
ResD	85.64	83.52	73.80	80.06	81.99	84.74	74.69	76.38	72.86	75.42	28.26	550.8
P	3.46	3.54	4.84	3.44	3.47	4.66	3.11	3.80	3.00	4.29	0.80	1.42
Ingredients (kg/Tn)	*Sow*		*Piglets-weaners*		*Growers*		*Fatteners cebo campo*					
	Gestating	Lactating	Starter	Transition	Gr [1]	Gr [2]	Fat [1]	Fat [2]	Final Fat	Quality Fat		
Soybean meal Brazil	94.24	179.2	163.8	159.6	128.9	117.0	31.70	53.00		26.00		
Spring pea Spain						60.00		125.00		150.0		
Sunflower oil Spain										57.00		
Wheat Spain	194.4	300.0	200.0	250.0	250.0	300.0	237.1	549.6	308.6	449.6		
Maize Spain	47.33	121.6	300.0	200.0	129.0		170.2	100.0	168.5	100.0		
Barley Spain	620.0	337.1	246.5	332.4	450.0	473.5	500.0	120.0	459.6	195.0		
Lard	12.93	30.28	29.80	21.33	10.00	28.00	21.00	32.00	23.34			
Salt			4.50			4.00		4.00		4.00		
Bicalcium phosphate			8.44			6.00		3.00		3.00		
Calcium carbonate			2.78			7.00		8.50		11.00		
L-lysine	1.08	1.65	2.65	4.33	1.83	1.50		1.90		1.40		
L-threonine		0.17	0.67	1.65	0.29							
L-valine			0.53									
L-methionine			0.37	0.66								
Premix	30.00	30.00	40.00	30.00	30.00	3.00	40.00	3.00	40.00	3.00		

Crude protein (CP). Organic matter (OM). Digestibility organic matter (OMd). Digested fibre content (ResD). Growing feed (Gr). Fattening feed (Fat).

[1] *Compound feed produced by Company 1.*

[2] *Compound feed produced by Company 2.*

Table S2. Data Iberian pig farms.

	Mean	Standard deviation	Minimum value	Maximum value
Surface				
Farm, ha	670.3	636.2	28.5	3000
Dehesa, ha	528.9	437.8	18	2000
Number of sows/farm	34.41	25.23	10	100
Number of boars/farm	4.00	3.79	1	14
Number of fatteners/farm				
Montanera	213.8	141.3	25	700
Cebo campo	213.3	256.2	35	700
Sows				
Total born/ farrowing, number	8.33	0.89	7	10
Born alive/ farrowing, number	7.55	0.60	6.5	8
Weaned/ farrowing, number	6.17	0.74	4.5	8
Weaning weight, kg	11.58	4.40	5.2	23
Weaning age, days	45.32	12.91	25	90
Fatteners				
Slaughter LW, kg	178.7	11.23	160	200
Age at slaughter, months	18.63	2.05	14	22.5

Number of farms (n=33). Number farms montanera (n=27). Number farms montanera and cebo campo (n=6).

Capítulo segundo

Structural typologies of Iberian traditional pig farms accounting their association with the economic and environmental performance

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Structural typologies of Iberian traditional pig farms accounting their association with the economic and environmental performance

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Simple Summary: Iberian traditional pig production is developed in the *dehesa* ecosystem where the Iberian pigs are linked to the sustainable use of natural resources. The presence of Iberian pigs is a key factor in the conservation of *dehesa* ecosystem, but the transformation of Iberian pig production from a traditional extensive to an industrial system has resulted in an increase in the number of animals produced. As a result, the *dehesa* ecosystem is endangered by overexploitation, being necessary the adoption of measures for a more sustainable Iberian traditional pig production according to the European policies focus on sustainable food production. From the analyses carried out, the relationship between characteristics of Iberian farm typologies and economic and environmental performance has been determined. Iberian farms outside the agro-environmental optimum should change farming practices to improve their sustainability. In this way, Iberian traditional farms can become more sustainable.

Abstract: At present, Iberian pig production is diversified in the *dehesa* ecosystem. The aim of this paper was to identify different Iberian traditional farm typologies based on economic and environmental performance with the aim of increasing the sustainability of these farms. Sixty-eight Iberian pig farms were evaluated through multivariate statistical tools to establish Iberian farm typologies. Factor analysis gave three factor components related to management, productivity and land yield that characterized the Iberian pig farms. Two groups of Iberian farms were determined: Multiple orientation and *Montanera* orientation. According to the results, *Montanera* farms generate lower environmental impacts and better economic benefits *per* unit of environmental impact. Consequently, analysis of the different farm types in Iberian traditional pig production can be used to generate best practice guidelines for a more sustainable Iberian pig production from an economic and environmental approach.

Keywords: farm diversification, agroecological intensification, farm productivity.

1. Introduction

The new European Union policies focus on sustainable food production through the European Green Deal (European Commission, 2019), proposing ambitious environmental goals for agriculture. Livestock practices play a key role in European agriculture production and economy, which has huge potential for contributing directly and indirectly to biodiversity and, environmental and economic sustainability (Broom et al., 2013; Varijakshapanicker et al., 2019).

The most diversified farms are the most sustainable (Franco et al., 2012) since multi-species livestock farming could conform a greater sustainability at farm level based on potential synergies and complementarities among livestock species on their production cycles and nutrient requirements (Mugnier et al., 2020). Complementarity on diet composition and natural resources-acquisition strategies will enable synergies between livestock species (Martin et al., 2020). Therefore, a better management of natural resources from the ecosystem by multi-species livestock is the optimal way to achieve sustainability (Mugnier et al., 2020).

There are several cases of livestock systems where different livestock species coexist around the world (Martin et al., 2020). Whereas the combination of ruminant species is common (Mugnier et al., 2020; Rowntree et al., 2020), the combination of ruminants and monogastrics is possible (Sehested et al., 2004). During the last decades, the multi-species livestock farming was replaced in favour of specialised and intensified livestock farming (Dumont et al., 2020), but the multi-species livestock systems are currently re-emerging due to multiple benefits to enhance farm economic, environmental and social performance (Martin et al., 2020). These benefits as long as locally relevant farming practices are implemented, especially on appropriate stocking rates where traditional or local farming practices are used (Martin et al., 2020).

The *dehesa* agroforestry system is based on multi-species traditional livestock production (Horrillo et al., 2020) where the livestock is linked to the sustained use of the pastures by ruminants and the consumption of acorns by Iberian fattening pigs (Rodríguez-Estévez et al., 2009). Therefore, the presence of Iberian pigs is a key factor in the *dehesa* multi-species farms to improve the integration of production enterprises (e.g. cattle and pig), becoming livestock and the *dehesa* a necessary tandem for the continuity of both (Rodriguez-Estevez et al., 2012).

Iberian pig production has increased by both the good image of its farming practices (García-Gudiño et al., 2021) and the high-quality of their products (Lorido et al., 2015). The transformation of Iberian pig production from a traditional extensive to an industrial system (Ríos-Núñez & Coq-Huelva, 2015) has resulted in the diversification of its production as a whole. The result is an increase in the number of produced units, thus opening trade channels and increasing the market niche. As a consequence, the *dehesa* ecosystem may be endangered by overexploitation (Ibáñez et al., 2014).

Previous studies carried out structural and economic typologies of *dehesa* farms (García et al., 2010; Gaspar et al., 2008; Milán et al., 2006). However, these studies have not considered the current diversification of Iberian pig production in the *dehesa* ecosystem as a result of the expansion of Iberian pig farm enterprise. Applying this typology will allow a better understanding of the role of Iberian pig farm structural characteristics and their connection with the environmental impacts generated, thus allowing to analyse of the sustainability of Iberian pig production in the *dehesa* ecosystem from an economic and environmental approach.

The aims of this paper can be described as (i) to identify different typologies based on technical, productive and economic aspects in Iberian traditional pig farms, and (ii) to analyse the environmental impacts generated and their economic and environmental benefits according to the Iberian farm type system.

2. Materials and Methods

2.1. Study area and description of Iberian pig production system

The *dehesa* ecosystem is located in the southwest of the Iberian Peninsula and cover an area of 6.7 million hectares (Horrillo et al., 2019). These agroforestry systems are characterised by the presence of holm and cork oaks, pastures, and shrubs where livestock use the available local natural resources (Escribano et al., 2018).

Iberian pig is a native breed of a medium-sized (Nieto et al., 2019). Iberian pig production system is based on the rearing of pigs under extensive or semi-extensive management, consuming compound feed and natural resources depending on the season (Benito et al., 2006). The different types of animals produced can be piglets (until 23 kg of live weight), growers (between 60 and 100 kg of live weight) or fatteners (up to 165 kg live weight on average). According to management, fatteners can be denominated as *montanera* or *cebo de campo* (Real Decreto 4/2014). When fatteners consume only natural resources (acorn and grass) are denominated as fatteners *montanera*. However, fatteners fed on natural resources available (mainly pastures) and compound feed are denominated as fatteners *cebo campo*. The age at slaughter (12 to 14 months) and the greater exercise under an extensive system contribute to high-quality meat of Iberian fatteners (Nieto et al., 2019).

2.2. Data Acquisition

Data were collected from 68 farms through questionnaires between 2016 and 2018. The questionnaires were conducted in the Iberian traditional pig area where the *dehesa* ecosystem is located (**Figure 1**). The questionnaires were carried out at different traditional Iberian pig regions according to the number of fatteners *montanera* produced (RIBER, 2016) in order to get a representative sample. The information collected was: farm area, facilities, machinery, number of animals (pigs and other species), data management (reproductive, feeding and health), work organization and sales (labour, economics and commercialization), social aspects and information about other activities (agriculture and other livestock species).

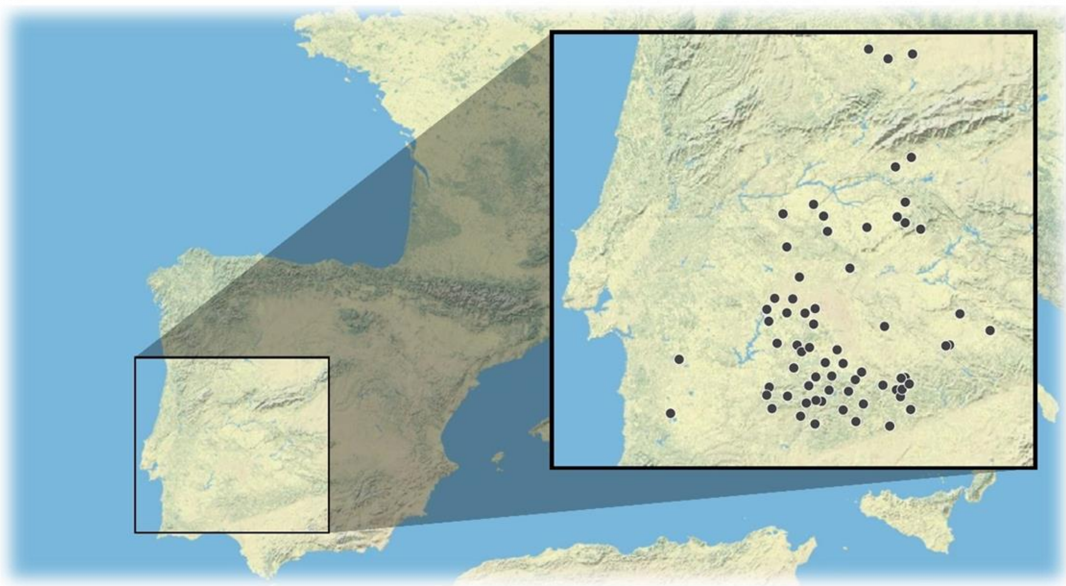

Figure 1. Distribution of Iberian pig farms in the survey (n=68).

2.3. Life Cycle Assessment

Environmental impacts were calculated for 36 Iberian pig farms representatively distributed over the study area. Some data needed for the environmental assessment could not be obtained from the remaining 32 farms. The definition of the system boundaries was derived from García-Gudiño et al. (García-Gudiño et al., 2020), being the functional unit one kilogram (kg) of live weight (LW) at the farm gate.

The environmental impacts calculated were climate change ILCD (CC, kg CO^2 eq), acidification ILCD (AC, molc H^+ eq), eutrophication CML baseline (EU, kg PO_4^{3-} eq), cumulative energy demand V1.8 non-renewable fossil+nuclear (CED, MJ) and land occupation CML non-baseline (LO, m^2·year). We used the International Reference Life Cycle Data System (ILCD) characterization method and Centre of Environmental Science (CML) characterization method of University of Leiden. Data were analyzed using Simapro software (version 8.5.2.0, PRé Consultants, Amersfoort, The Netherlands).

The economic value of environmental impacts from Iberian pig production was calculated as a ratio of the gross margin to the environmental impact generated. The gross margin was calculated as the difference between incomes derived from Iberian pig production and variable costs (Angón et al., 2013; Morantes et al., 2017).

2.4. Statistical methods and data analysis

Multivariate statistical tools were utilized to establish Iberian farm typologies from technical, economic and management data. The development of typology was made from the methodology used by Giorgis et al. (2011), Gaspar et al. (2011), Toro-Mújica et al. (2012) and Rivas et al. (2015), which consists of three stages: review and selection of variables, factor analysis and cluster analysis.

Thirty-four variables were analysed from the survey data, from which 26 variables were selected (CV > 50%). A preliminary step was the assessment of the suitability of the data set. The evaluation was made by comparing the Pearson (rPEAR) and partial (rPAR) correlations between the observed variables (Manca et al., 2016) to eliminate uncorrelated variables and the one with the lowest coefficient of variation of each pair with linear dependence. Through the selection process were obtained the following 13 variables were obtained: farm surface area (ha), *Dehesa* land use (%), pig stocking rate (LU/ha), sows (n), sows *per* 100 kg of pig (n), piglets produced *per* fattened pig (n), kg of live weight *per* surface area (kg/ha), kg of live weight from fatteners *montanera per dehesa* area (kg/ha), *Dehesa* production (%), *Montanera* income in relation to Iberian pig production (%), farm surface *per* annual work unit (ha/AWU), labour productivity (kg/AWU) and incomes *per* annual work unit (€/AWU) (see description in **Table 1**).

Secondly, factor analysis was used to reduce the number of variables and summarise most of the variability. The variables were standardized to avoid influence by the use of different scales. Analysis of principal components was used as the extraction method to accurately calculate factor scores for each farm (Rivas et al., 2015), and varimax rotation was chosen to ensure orthogonality of the extracted factors (Kaiser, 1960). The Bartlett sphericity test and the Kaiser–Meyer–Olkin index were applied to verify sample adequacy (Cerny & Kaiser, 1977; Köbrich et al., 2003).

In the final stage, the Iberian pig farms were classified into groups using a cluster analysis based on the individual factor scores calculated for each farm using coefficients from the rotated factor matrix. The hierarchical groups were developed based on Ward's method, using the Euclidean, squared Euclidean and Manhattan distances (Rangel et al., 2020). The optimal number of clusters was selected using the Elbow method (Rivas et al., 2015). The optimal cluster were tested using discriminant analysis and analysis of variance (Toro-Mujica et al., 2012).

Cluster groups were characterised and compared from an economic, technical and environmental approach using Student t-test to highlight contrast between groups of farms (Perea et al., 2014). To facilitate comparison between clusters, indices derived from the observed variables were calculated (group mean/global mean) and presented in figures. All statistical analyses were performed using the SPSS 19.0 software package (SPSS, 2010).

Table 1. Description of structural variables used in factor analysis.

Variable	Description, units
Montanera income	*Montanera* income/pig production income, %
Dehesa production	kg *dehesa* area/kg total surface area, %
Dehesa land use	Utilized *dehesa* area/Total *dehesa* area, %
Pig stocking rate	Pig livestock unit *per* ha, LU/ha
kg pig production	kg of live weight from pig production *per* total surface area, kg/ha
Sows production	Sows *per* 100 kg of pig, n
kg AWU*	kg of live weight from pig production/Annual work unit, kg/AWU
Income AWU*	Pig production income/Annual work unit, €/AWU
Sows	Number of sows, n
Piglets output	Piglets produced *per* fattened pig, n
Area AWU*	Total surface area/Annual work unit, ha/AWU
Farm surface	Total surface area, ha
kg *montanera*	kg of live weight from fatteners *montanera per dehesa* area, kg/ha

*AWU: Annual work unit

3. Results and Discussion

3.1. Characteristics of the Iberian farms in the dehesa ecosystem

The structural data obtained in Iberian traditional pig farms showed a great variability like other studies on the *dehesa* ecosystem (Díaz-Gaona et al., 2019; García et al., 2010; Gaspar et al., 2008; Maroto-Molina et al., 2018; Milán et al., 2006). The farms studied had a large size, with a median farm surface area of 333.5±533.5 ha (M±SD), similar to values obtained in other studies of the *dehesa* (Milán et al., 2006). Multi-species livestock farming was the main activity of *dehesa* farms, obtaining a median value of 150.9±181.8 LU. Because of the high farm surface, the average stocking density obtained was 0.49 LU/ha, which is similar to other studies (Franco et al., 2012; Gaspar et al., 2007). The presence of Iberian pigs is important because more than one-third of LU belong to this local breed of swine, being in line with Maroto et al. (Maroto-Molina et al., 2018).

Even so, a high proportion of total farm income (58.8%) came from Iberian pig production.

Focusing on Iberian pig production, the majority of Iberian farms were farrow-to-finish farms, but at least 20% of the farms focused strictly on rearing and fattening of Iberian pigs obtained from other farms. The number of sows was 20.00±32.96 *per* farm with a median production of 6.25±0.66 weaned piglets *per* farrowing, being similar to other studies on Iberian pig extensive systems (Duarte et al., 2013). The median annual piglet production was 240.0±597.92 piglets *per* farm. Approximately a quarter of the piglets produced were sold before the fattening period. On the other hand, the median production of fattened pigs was 154.5±282.4 fatteners *per* Iberian farm. The majority of fattened pigs (88.7%) were fed only with local natural resources, becoming fattening *montanera* the main activity of the traditional Iberian pig production. Fattening dominates the agricultural economy of these traditional systems representing 93.3% of the Iberian pig production's and farm income.

In summary, the general data obtained in the present study are in line with the mixed beef cattle, sheep, and Iberian pig farms in wooded *dehesas* previously studied (Gaspar et al., 2007). These farms are characterised by a high production due to the sale of fatteners exclusive fed on natural resources. The great variability observed in the data obtained indicates the existence of different Iberian farm types and justifies establishing a structural typology for the Iberian pig farms in the study.

3.2. Factors characterizing the Iberian farms

The variables used in the characterisation of Iberian pig farms are described in **Table 1**. The Bartlett's sphericity test showed a satisfactory probability value ($p < 0.05$) and the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy showed a value of 0.77, indicating the suitability of the analysis. KMO value obtained was similar to previous studies in other livestock extensive systems (Perea et al., 2014; Rivas et al., 2015).

The first three factors accounted for 73.14% of the original variability (**Table 2**), that is considered a satisfactory percentage (Malhorta, 2004). These results are similar to previous studies in terms of the proportion of variance explained and the number of factors extracted relative to the number of original variables used (Gaspar et al., 2008; Giorgis et al., 2011; Perea et al., 2014; Rivas et al., 2015; Toro-Mujica et al., 2012).

The first factor (F1) was denominated "livestock management" and explains 31.16% of the variability. F1 reveals an inverse relationship between the level of intensification and optimal use of natural resources of livestock more embedded in the *dehesa* ecosystem. The results are in line with other studies carried out in the *dehesa* ecosystem (García et al., 2010; Gaspar et al., 2008) where F1 is related to the level of intensification and feed management.

The second factor (F2) was called "scalability". F2 expresses the relationship between reproductive performance and income *per* AWU of farms, accounting for 23.91% of the variance. A higher number of livestock productivity units (sows and piglets produced) allows the creation of more opportunities for farm enterprises (sale of piglets, growers or fatteners) but increases labour productivity more extensively than labour force.

Finally, the third factor (F3) justifies 18.07% of the variance and showed an inverse relationship between Iberian pig production (kg) and farm surface. F3 was denominated "land yield". In other studies, farm dimension variables were part of F1 (Díaz-Gaona et al., 2019; Toro-Mujica et al., 2012).

Table 2. Factors extracted and saturation coefficients with the original variables after varimax rotation. Bold figures belong to factor extraction.

Variable	F1	F2	F3	Communality
Montanera income	**0.938**	-0.077	0.051	0.888
Dehesa production	**0.925**	-0.089	0.037	0.864
Dehesa land use	**0.848**	-0.003	-0.037	0.721
Pig stocking rate	**-0.690**	0.173	-0.433	0.693
kg pig production	**-0.653**	0.243	**-0.504**	0.739
Sows production	**-0.551**	-0.259	0.101	0.381
kg AWU	0.095	**0.930**	0.154	0.898
Income AWU	0.187	**0.911**	0.152	0.888
Sows	-0.203	**0.758**	0.235	0.671
Piglets output	-0.301	**0.616**	-0.228	0.522
Area AWU*	0.092	0.245	**0.875**	0.834
Farm surface	0.100	0.350	**0.815**	0.796
kg *montanera*	0.445	0.326	**-0.557**	0.614
Variance (%)	31.16	23.91	18.07	-
Eigenvalue	4.24	3.28	1.99	-

*AWU: Annual work unit

3.3. Typology in Iberian farms established

Cluster analysis, which presented the most significant results, was the solution of two groups with Ward's method, based on the Euclidean distances. The three factors differentiated significantly between the two groups of Iberian farms, defining the Iberian farms in each group based on the main characteristics (**Table 3**).

Group I concentrated 45.59% of farms (n=31) and was defined as "Multiple orientation". On these Iberian farms, several types of pig (piglets, growers, and fatteners) are produced, and Iberian pig production has a higher level of intensification. Group II included 54.41% of Iberian farms (n=37) being denominated "*Montanera*". These farms are characterised by an optimal use of natural resources in the *dehesa* where the fattener production is its main production. The *Montanera* farms showed homogeneity in their values, while the Multiple orientation farms presented a higher dispersion in the variables with respect to the three factors (**Figure 2**). The main cause is the different types of products in the Multiple orientation farms, while the *Montanera* farms are mainly focused on fattening production.

Table 3. Differences of Iberian farm types between technical and environmental variables.

Variable	All farms	Multiple Orientation	*Montanera*	SDM	P-value
Technical variables					
Montanera income	83.41	70.08	94.58	27.71	< 0.001
Dehesa production	81.93	68.19	93.44	28.65	< 0.001
Dehesa land use	81.37	67.74	92.78	28.81	< 0.001
Pig stocking rate	0.17	0.22	0.13	0.25	ns
kg pig production	136.9	153.7	122.8	153.2	ns
Sows production	0.12	0.21	0.06	0.43	ns
kg AWU*	26,010	33,775	19,503	21,614	< 0.01
Income AWU*	74,862	94,459	58,444	56,805	< 0.01
Sows	31.24	50.68	14.95	32.96	< 0.001
Piglets output	4.47	8.38	1.19	21.28	ns
Area AWU*	288.0	418.6	178.6	239.3	< 0.001
Farm surface	517.8	793.5	288.7	533.5	< 0.001
kg *montanera*	113.6	100.7	124.4	89.70	ns
Environmental variables					
CC	3.76	4.03	3.49	33.40	< 0.05
AC	0.10	0.10	0.09	0.67	< 0.05
EU	0.05	0.053	0.047	0.34	< 0.05
CED	23.59	25.92	21.26	6.54	< 0.05
LO	38.72	44.25	33.19	64.08	ns
CC margin	0.63	0.51	0.77	0.27	< 0.01
AC margin	23.75	19.72	28.44	9.83	< 0.01
EU margin	47.18	38.94	56.79	19.70	< 0.01
CED margin	0.10	0.09	0.12	0.03	< 0.05
LO margin	0.07	0.05	0.09	0.04	< 0.01

*AWU: annual work unit; CC: Climate change; AC: Acidification; EU: Eutrophication; CED: Cumulative energy demand; LO: Land occupation; SDM: Squared deviation from the mean.

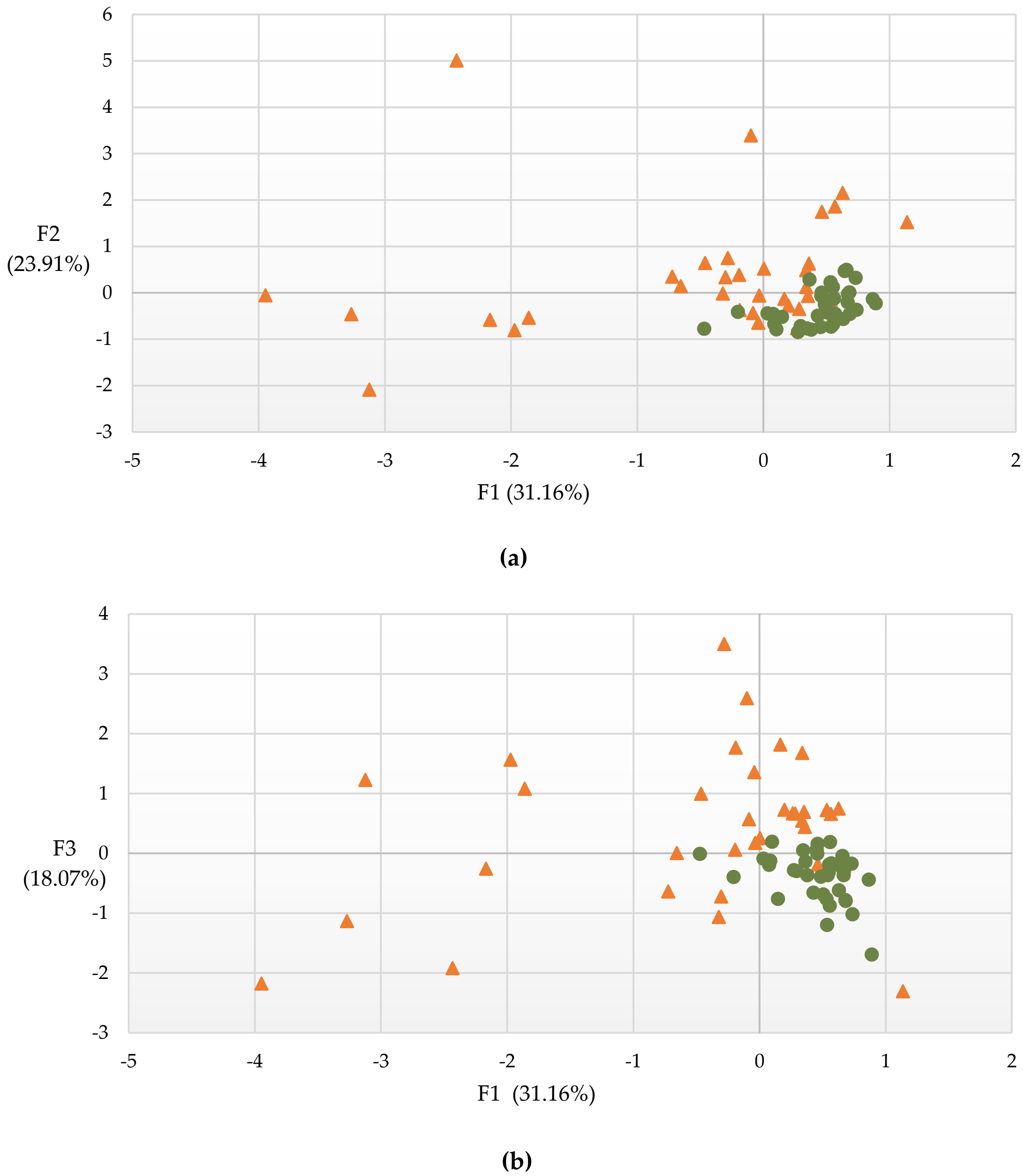

Figure 2. Position of Iberian farms according to the scores obtained for (a) F1 and F2, and (b) F1 and F3 (orange triangle - Multiple orientation, green spot - *Montanera*).

F1 showed significant differences between the different Iberian pig farms types obtained in relation to the integration of livestock into the *dehesa* ecosystem (**Figure 3**). The main cause is a major use of natural resources because of a greater use of *dehesa* area on the *Montanera* farms. For this reason, Iberian pig production depends economically and productively on fattening system based on natural resources on the *Montanera* farms. However, all other variables included in F1 indicating the level of intensification showed no significant differences between the farms studied, possibly due to the large variability among Multiple orientation farms, although the mean values obtained were higher in Multiple orientation farms than in *Montanera* farms (**Table 3**).

On the other hand, F2 showed a significant differentiation between the Iberian farm types obtained through their variables (**Figure 3**). The productivity of labour was 70% higher in Multiple orientation farms in terms of kilograms of live weight from pig production and 60% higher in terms of pig production income compared to *Montanera* farms. The main reason for the higher labour productivity is three times more sows in Multiple orientation farms than in *Montanera* farms. A higher number of sows produces a higher number of piglets and because of the limitation of fatteners *per dehesa* hectare according to Spanish legislation (Real Decreto 4/2014), pig production on Multiple orientation farms needs to be diversified. Therefore, an increase in reproductive performance results in the production of surplus piglets or growers on Multiple orientation farms. In comparison with *Montanera* farms, reproductive management is smaller scale more adjusted to numbers of weaned piglets according to the wooded area (0.25-1.25 fatteners/ha). For this reason, the number of piglets produced *per* fattened pig is substantially higher in Multiple orientation farms than in *Montanera* farms. However, possibly due to the great data variability in Multiple orientation farms, no significant differences were observed between the Iberian farm types.

With regard to the variables that are part of F3, the Multiple orientation farms had a larger farm surface area than the *Montanera* farms (**Figure 3**). Therefore, labour *per* hectare is lower in Multiple orientation farms because a larger farm surface does not require more labour in extensive livestock systems (Gaspar et al., 2008). However, both Iberian farms types obtained a similar production performance in terms of fattening *montanera* due to the maximum allowed stocking density of fatteners in the *dehesa* (Real Decreto 4/2014), and also in terms of total Iberian pig production total due to the great variability of the data obtained from Multiple orientation farms.

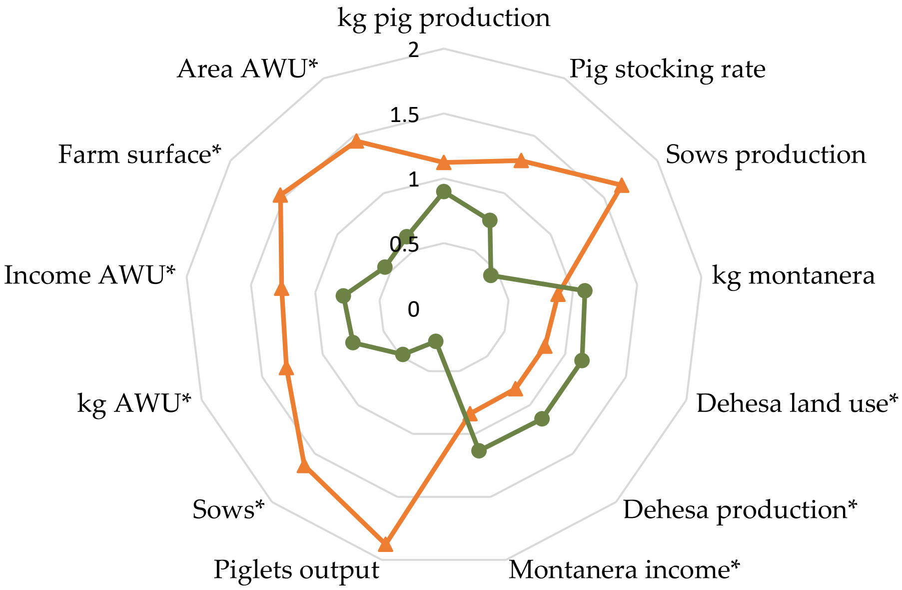

Figure 3. Cluster comparison using indices (group mean / global mean) derived from the observed variables used in the factor analysis (orange triangle-Multiple orientation, green spot-*Montanera*). The asterisked variables were significantly different between clusters. AWU: annual work unit.

As a result, "Multiple orientation" is the group including the biggest farms, both in land and in the number of sows. They are characterised by having the biggest values ($p < 0.05$) of productivity of labour, measured either in kg/AWU or €/AWU. In contrast, "*Montanera*" is the group including the smallest farms (ha), where the number of sows is determined by the maximum number of finishing pigs produced *per* hectare due to a production linked to the natural resources provided by the *dehesa* ecosystem.

3.4. Environmental performance according to the Iberian farm type

Environmental performance from Iberian traditional pig production were analysed for both Iberian farm types as a result of cluster analysis (**Table 3**). Iberian farm types showed significant differences in the estimated environmental impacts (CC, CED, AC and EU), indicating lower environmental impacts *per* kg of LW produced on *Montanera* than in Multiple orientation farms. The main reason for the lower environmental impacts on *Montanera* farms is an optimal use of natural resources available in the *dehesa* ecosystem (Espagnol & Demartini, 2014; García-Gudiño et al., 2020). Indices were used for a standardized comparison between Iberian farm types (**Figure 4**). *Montanera* farms determine Iberian pig production with respect to the *dehesa* hectares available for an optimal use of its natural resources. However, Multiple orientation farms have a strong dependency on feedstuff inputs due to greater pig production, being the principal cause of higher environmental impacts (Sporchia et al., 2021). Multiple orientation farms have improved productivity through increasing level of intensification (Ryschawy et al., 2012) but cause negative effects on the environment (Ilea, 2009). On the other hand, no differences were found between the two Iberian farm types in LO impact regarding fatteners *montanera* production in both farm types. The use of large surfaces to provide natural resources use (Benito et al., 2006) is the cause of the increase of LO in Iberian traditional pig production (García-Gudiño et al., 2020). In general, Iberian traditional farms show higher environmental impacts than conventional farm systems *per* kg of LW (Dourmad et al., 2014). However, when environmental impacts were expressed *per* hectare of land use, pig production in traditional farms had the lowest environmental impacts since there is more available area *per* pig (Dourmad et al., 2014; Monteiro et al., 2019).

The variables of the three factors can influence the environmental impacts generated. The F1 variables tend to an optimal management of natural resources in the *dehesa* ecosystem, resulting in a reduction of environmental impacts in *Montanera* farms (García-Gudiño et al., 2020). Furthermore, F2 variables are related to productive performances in Iberian farms through an increased number of sows. The number of sows increases the number of pigs produced and as a result animal feed consumption (Gaspar et al., 2007), increasing the environmental impacts from feed consumption (Sporchia et al., 2021) in Multiple orientation farms. In this case, environmental impacts would be mitigated through the reduction of crude protein and amino acids in compound feeds according to low nutritional requirements of local breeds (Monteiro et al., 2019). Finally, F3 has no influence on the environmental impacts because the variables related to Iberian pig production (kg/ha) showed no significant differences between Iberian farm types.

The gross margin *per* kilogram of live weight from pig obtained was different between Iberian farm types ($p < 0.05$), being 15% superior in *Montanera* farms than in

Multiple orientation farms. A better price of fatteners *montanera* on the market (Gaspar et al., 2009) and a lower use of external feed in pig production (Real Decreto 4/2014) are the causes of a better gross margin in *Montanera* farms. However, diversification on Multiple orientation farms reduce economic risk due to a wider diversity of products produced (De Roest et al., 2018).

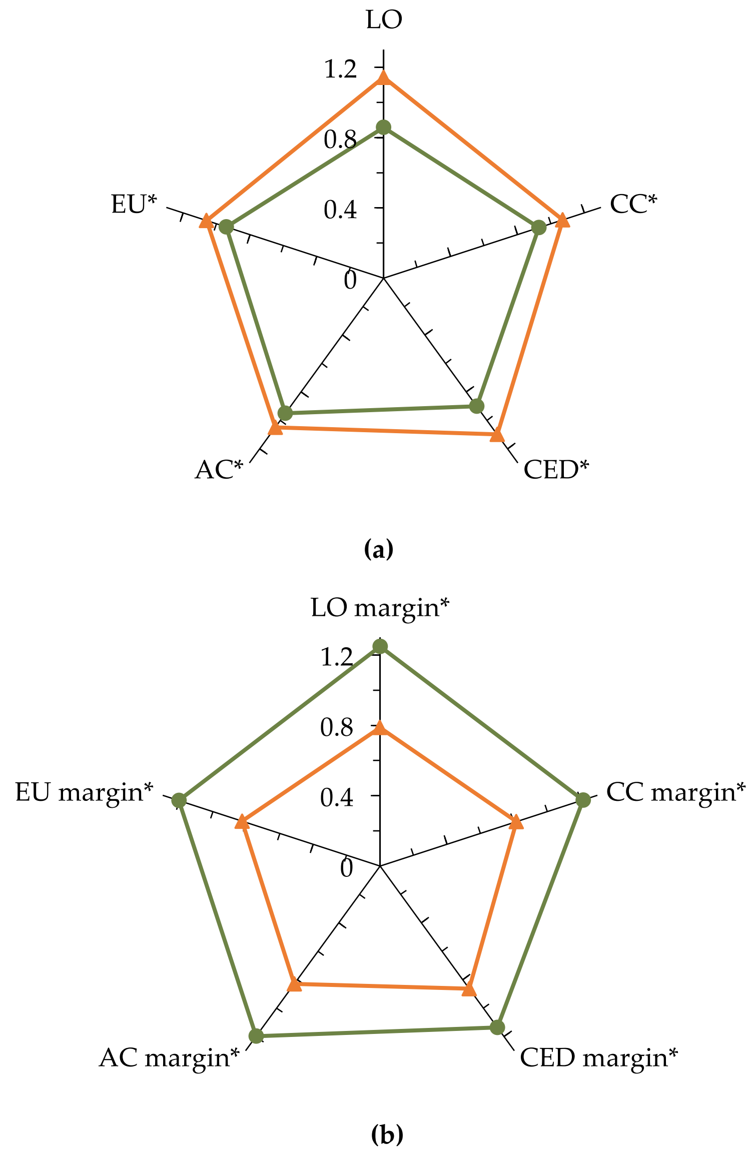

Figure 4. Cluster comparison using indices (group mean / global mean) derived from (**a**) environmental impact variables and (**b**) their economic values (orange triangle-Multiple orientation, green spot-*Montanera*). The asterisked variables are significantly different between clusters. AC: Acidification; EU: Eutrophication; CED: Cumulative energy demand; LO: Land occupation.

The economic benefit *per* unit of environmental impact was calculated for the different Iberian farm types in order to provide an environmental and economic benefit. The *Montanera* farms obtained a significantly higher economic return from environmental impacts than the Multiple orientation farms (**Figure 4b**). The smallest difference was for CED margin (€/MJ), which was 32% superior on *Montanera* farms compared to Multiple orientation farms. Production of concentrate feedstuffs highly contributes to CED impact in livestock production (Wilfart et al., 2016), but differences in feed management between the Iberian pigs mainly occur during the fattening period (Real Decreto 4/2014), being a reduced period compared to the complete production cycle of the Iberian pig (Benito et al., 2006). Because of this, the smallest differences between Iberian farm types were found in CED impact. Conversely, the biggest difference corresponded to LO margin (€/m2·year), which was 59% superior in *Montanera* farms compared to Multiple orientation farms reasoned by a better price of fatteners *montanera* on the market (Gaspar et al., 2009), as mentioned above.

Overall, *Montanera* farms obtained better environmental values and economic benefits *per* environmental unit produced than Multiple orientation farms. On the one hand, the environmental impacts of Iberian pig production were 9-18% lower on *Montanera* farms compared to Multiple orientation farms, except for LO impact where the difference was 33% based on the increase of animal feed consumption in Multiple orientation farms (Gaspar et al., 2007) (**Figure 4a**). On the other hand, economic benefits *per* environmental unit produced were 32-59% higher in *Montanera* farms compared to Multiple farms (**Figure 4b**), resulting economic-environmental differences more significant than environmental differences between Iberian farms types obtained. According to the results, *Montanera* farms are a more ecologically self-regulated livestock production generating lower environmental impacts and better economic benefits *per* unit of environmental impact.

Several authors pointed out that European policies have a significant potential to contribute to sustainable development of livestock farming by economically favouring the most environmentally friendly or sustainable farms (Muñoz-Ulecia et al., 2021; Scown et al., 2020). Adjusting Iberian farms towards a *Montanera* orientation would result in more environmentally friendly farms, contributing to the conservation of the *dehesa* ecosystem where these farms are located with an optimal profitability based on better value of its product on the market (Gaspar et al., 2009). Moreover, since pig production yield (kg/ha) was no different between Iberian farms types obtained, it is possible to reduce environmental impacts and become economically profitable in Iberian traditional pig production.

4. Conclusions

Establishing the proposed methodology determines the environmental and economic consequences of the structural characteristics of the different Iberian farm types, generating a practical guide aimed towards more sustainable Iberian pig production from an economic and environmental approach.

Across to the proposed typology is intended to provide a level of analysis that can also be translated into practical advice to decision-makers. Iberian pig farms outside the agro-environmental optimum, should change their farming practices in order to improve the economic and environmental performance of livestock production in line with new European policies. Iberian pig farms of different management systems should be monitored annually through established typology, being an optimal option for the evaluation of the sustainability on Iberian traditional farms. With this proposal, Iberian traditional pig farms could become more sustainable in the shortest run.

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Capítulo tercero

Analysis of the sustainability of fattening systems for Iberian traditional pig production through a technical and environmental approach

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Analysis of the sustainability of fattening systems for Iberian traditional pig production through a technical and environmental approach

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Simple Summary: Iberian traditional pig production has been linked to the use of the natural resources of the *dehesa* ecosystem. In the last decades, the Spanish livestock sector has experienced a significant transformation towards the intensification of livestock systems. The intensification of the system combined with the increased demand for high-quality Iberian products resulted in a greater demand for feedstuffs as inputs into the Iberian pig production system. For these reasons, the Iberian pig exploitation in the *dehesa* ecosystem should be studied considering economic and environmental criteria to identify strategies for more sustainable livestock production. From the analyses carried out, the relationship between livestock management and environmental values obtained has been determined. Iberian traditional pig production has room for improvement in terms of economic and environmental values. In order to achieve this, appropriate fattening strategies should be implemented to optimize the use of available resources and improve economic-environmental performance for sustainable development. The importance of exploring sustainable management on this animal system derives because a sustainable Iberian traditional pig production has an important role in maintaining the population in rural areas through livestock activity as an economic engine.

Abstract: At present, two types of fattening are carried out in Iberian traditional pig production. The *montanera* is the fattening system where fatteners are fed on acorns and pasture in the *dehesa*, and *cebo de campo* is the fattening where the pigs are fed on compound feed and natural resources, mainly pasture. The aim of this paper is to analyze Iberian fattening production from an economic and environmental approach in order to identify fattening strategies to increase the sustainability of this traditional livestock activity. Based on technical-economic and environmental variables, the differences between Iberian farms according to the types of fattening were determined using discriminant analysis techniques. The model based on environmental variables showed a greater predictive ability than that found in the model based on technical-economic variables. Consequently, environmental variables can be used as reference points to classify the Iberian farms according to the type of fattening. Furthermore, canonical correlation analysis allowed to study the relationships between both sets of variables, showing that environmental values had a strong correlation with technical-economic variables. The results of this study show that it is possible to improve the sustainability of Iberian traditional pig production through fattening strategies in both types of fattening.

Keywords: local breed, feeding systems, multivariate analysis.

1. Introduction

Iberian traditional pig production has a significant role in the Spanish pig industry, where intensive systems are predominant (De Miguel et al., 2015). The sustainability of traditional livestock systems being less competitive than conventional systems (Gaspar et al., 2009a) has been possible by added values offered (García-Gudiño et al., 2020; Lorido et al., 2015; Temple et al., 2011). This greater product differentiation and value-adding over time has shifted the interest to outdoor pig production systems by consumers (Rodriguez-Estevez et al., 2012) with a more critical view towards intensive livestock production (Clark et al., 2019). Therefore, according to this reasoning, different production managements can be found in the actual Iberian pig sector (Real Decreto 4/2014), increasing the number of fatteners produced annually (RIBER, 2020).

At present, two different fattening types are developed in the *dehesa* and count with a specific legislation (Real Decreto 4/2014): *montanera* and *cebo de campo*. The *montanera* is the traditional fattening type based on local natural resources under extensive management (Ríos-Núñez & Coq-Huelva, 2015). The limitation of *dehesa* hectares (Mesías et al., 2009) form the basis of the human intervention that increases the use of external inputs in Iberian pig production. For this reason, the *cebo de campo* emerged as the fattening characterized by the use of natural resources combined with compound feed. Decreased use of natural resources in *cebo de campo* has resulted in an exponential increase in the number of fatteners produced per year to over one million in the Iberian traditional pig production area (RIBER, 2020). However, the number of animals produced between the two fattening types is approximately the same.

The perfect adaptation of Iberian breed to the *dehesa* ecosystem has promoted the persistence of this local breed and its productive system (Lopez-Bote, 1998). However, the traditional image of the Iberian pig in the *dehesa* has been denatured because of the large increase of animals produced (Casas et al., 2015). This higher demand has led to environmental stress at the *dehesa*, which endangers the traditional livestock system. The overexploitation of the agroecosystem can lead to a series of negative consequences such as soil erosion (Ibáñez et al., 2014) or decrease in oak regeneration (López-Sánchez et al., 2014).

Because Iberian pig and the *dehesa* ecosystem constitute a real symbiosis (Rodriguez-Estevez et al., 2012), pig production and the agroforestry system must be assessed in a combined approach. In this way, pig production could be economically viable and environmentally friendly (Dolman et al., 2012), both crucial for the preservation of the *dehesa* and the future of livestock as economic engine (Horrillo et al., 2019) to sustain the population in rural areas (Rodriguez-Estevez et al., 2012). Previous works on environmental assessment showed a completely different conclusion of that resulted from an economic analysis in livestock systems (Asmild & Hougaard, 2006). Studies on livestock production in the *dehesa* have addressed the technical-economic (Gaspar et al., 2007, 2009a, 2009b) and environmental assessment (García-Gudiño et al., 2020; Horrillo et al., 2020, 2021) on singles pieces in general. Therefore, it is of great importance to evaluate the actual situation of Iberian pig production in the *dehesa* through different economic and environmental analytical approaches aiming to balance the economic and environmental pillars of the sustainability of the traditional Iberian pig production.

The purposes of this paper can be described as (i) exploring the differences in Iberian farms according to the fattening types based on technical-economic and environmental approach, (ii) identifying the characteristics that can be reference points to differentiate the fattening types, and (iii) proposing strategies to improve sustainability of Iberian traditional pig production.

2. Materials and Methods

2.1. Description of the Pig Fattening at the Iberian Traditional Pig Production

The growing period in this traditional system is based on extensive or semi-extensive management from 23 kg to 95–105 kg of live weight (Nieto et al., 2019). The growers are fed with compound feed and they consume different natural resources depending on season (Olea et al., 1990).

Differences of management are mainly found in the finishing or fattening period (**Table 1**). According to the Spanish legislation (Real Decreto 4/2014), the finishing period can be appointed as *montanera* or *cebo de campo* in the *dehesa*. The types of fattening are defined by stocking density, feeding, and age at slaughter. According to stocking density, the *montanera* should rear between 0.25 and 1.25 fatteners per hectare depending on the available wooded area. On the other hand, the stocking density is fixed in 15 fatteners per hectare in the *cebo de campo* during the finishing period. Regarding the feeding, fatteners should consume only natural resources (acorn and grass) in the *montanera* while fatteners are fed with compound feed and natural resources available (mainly pastures) in the *cebo de campo*. In terms of the minimum age at slaughter, it is fixed on 14 months in the *montanera*, and 12 months in the *cebo de campo*. In both cases, the fattening period out of the life cycle of the animal must last a minimum of 60 days. With the feeding availability in mind, the *cebo de campo* can be developed throughout the year, while the *montanera* can only occur between October and March due to the availability of acorns in the *dehesa*.

Table 1. Requirements of management in Iberian fattening period according to the legislation (RD 4/2014).

Requirements Fattening Period	*Montanera*	*Cebo de Campo*
Feeding	Natural resources (acorns and grass)	Compound feed and natural resources (grass)
Stocking density	0.25–1.25 animals/ha	15 animals/ha
Minimum duration	60 days	60 days
Minimum age at slaughter	14 months	12 months

2.2. Data Acquisition

Data were collected through questionnaires from 36 farms in the Iberian traditional pig area (SW Spain). Data achieved for this study were farm area, number of animals (pigs and other species), productive (e.g., daily ration, live weight, age at slaughter) and reproductive (e.g., fertility, prolificacy) data, economic and management aspects, inventory (machinery and facilities), and information about other activities (agriculture and livestock).

Environmental variables employed were derived from García-Gudiño et al. (2020). Global warming (GW, kg CO_2 eq) and land occupation (LO, m^2·year) were used for the environmental assessment in the present study. Analyses of Life Cycle Assessment (LCA) were performed with Simapro software (version 8.5.2.0, PRé Consultants, Amersfoort, The Netherlands). The functional unit was one kilogram of live weight at farm gate.

Technical and environmental variables are described in **Table 2**. Some of them are economic variables that are related either to technical or environmental aspects.

Table 2. Technical and environmental variables used to evaluate fattening types in Iberian farms (n = 36).

Variable	Description	Mean	SE [1]
Technical variables			
Farm surface	Total surface area, ha	631.60	104.02
Dehesa land use	Utilized *dehesa* area/Total *dehesa* area, %	79.25	5.34
Pig stocking rate	Pig livestock unit per ha, LU/ha	0.12	0.02
Sows	Sows per 100 kg of pig	0.16	0.09
Piglets output	Piglets produced per fattened pig	1.48	0.19
kg *montanera*	kg of LW from fatteners *montanera* per *dehesa* area, kg/ha	95.70	17.21
kg total pig production	kg of LW from pig production per farm surface, kg/ha	106.49	17.67
ha value *	Production value per ha, €/ha	298.15	43.93
LU value *	Production value per pig livestock unit, €/LU	2554.4	100.69
Feedstuffs inputs	Animal feedstuffs per ha, kg/ha	212.69	92.77
Environmental variables			
GW	Global warming, kg CO_2 eq	3.75	0.75
LO	Land occupation CML non baseline, m^2·year	38.72	3.60
GW value *	Production value per GW, €/CO_2 eq	0.795	0.027
LO value *	Production value per LO, €/m^2·year	0.092	0.007

* Economic variables relating to technical and environmental aspects. [1] SE: standard error. LU: livestock unit; LW: live weight; GW: global warming; LO: land occupation.

2.3. Statistical Analysis

Preliminary testing of data was carried out to determine outliers to be discarded before analysis, using the Grubb`s test, and to determine Pearson correlations to avoid variables that presented a correlation coefficient with an absolute value >0.95 (Jäntschi, 2019). Because data had different measurement units, variables were standardized to zero mean and a unit standard deviation.

Farms were classified into two groups according to the type of fattening: *Montanera* farms (MF) if more than 90% of the fattened pigs were certified as Iberian acorn-fed (Real Decreto 4/2014), and diversified farms (DF) otherwise. In DF, Iberian acorn-fed pigs are less than 90% of the pigs fattened on the farm. The rest of the fattened pigs are fattened through the *cebo de campo*. Therefore, the types of fatteners produced (*montanera* or *cebo de campo*) in DF are more diverse than in MF.

Multivariate analysis techniques were used to analyze differences and similarities in technical and environmental variables among fattening types, and to evaluate the specific relationships between technical and environmental variables. To discriminate between the two groups (MF/DF), three complementary and sequenced techniques were applied in the following order: canonical discriminant analysis, stepwise discriminant analysis, and discriminant analysis. These techniques have been applied in previous studies on livestock systems (Caballero-Villalobos et al., 2018; Figueroa et al., 2020; Miles et al., 2020; Rivas et al., 2019; Zurita-Herrera et al., 2011).

Canonical discriminant analysis is a dimension-reduction technique related to principal component analysis and canonical correlation, which gives information about the similarities of the fattening types implemented in Iberian pig farms. It was applied to all the variables described in **Table 2**. Given a classification character several variables, canonical discriminant analysis derives a set of new variables, called canonical functions, which are linear combinations of the original variables that summarize between-group variation in the data, highlighting their differences (Figueroa et al., 2020).

The minimum number of variables able to discriminate between the two groups was obtained after performing a stepwise discriminant analysis on two sets of variables: those related to technical variables, those related to the environmental variables of the fattening types, and those related to both sets of variables. This procedure selects the variables to include in the model based on how much they contribute to decrease Wilks' λ. In the first step, the most discriminating variable enters into the model, and in subsequent steps, the entry or removal of variables is evaluated according to an entry and remove threshold that was set at 0.05 and 0.10, respectively. To avoid information redundancy, a tolerance level of 0.01 was set. The steps are repeated until no more variables can be entered or removed, or until the maximum number of steps is reached, which was set as twice the number of original variables in each model. The efficiency of the discriminant power of a given model was determined using the Wilks' λ test of significance. The effective separation of groups was assessed using Mahalanobis distance and the corresponding Hotelling's T^2 test (De Maesschalck et al., 2000).

The canonical discriminant analyses were repeated with the selected variables derived from stepwise discriminant analyses to obtain the most plausible canonical functions, and from these, discriminate between the fattening types. The predictive ability of each model was tested using the absolute assignment of individuals to the preassigned group (Mardia et al., 2000).

The second step was to study the existing relationships between technical and environmental variables of the fattening types. Canonical correlation analysis was deemed appropriate because it provides not only the magnitude of the relationships that may exist between groups of variables but also a quantification of the relative contribution of each variable to those relationships (Tabachnick et al., 1996). Canonical correlation analysis complements discriminant analysis, because the latter explores only associations between data without explaining why they exist (Figueroa et al., 2020).

Canonical correlation analysis is a multivariate analysis method based on the linear relationship between two multidimensional variables, X (technical) and Y (environmental). The aim of this analysis is to find linear combinations ($U = a^TX$ and $V = a^TY$) so that the correlation between U and V is maximized. Such linear combinations reflect the relationship between both sets of variables (Caballero-Villalobos et al., 2018; Yin, 2004). The basic principle of canonical correlation analysis is the construction of subsequent pairs of canonical variables (Ui, Vi), that are linear combinations of the originals, so that each pair is orthogonal to the previous and represents the best explanation of the Y set (formed by q dependent variables) with respect to the X set (formed by p independent variables) that has not been obtained by the previous pairs (Liu et al., 2009; Rivas et al., 2019). All statistical analyses were performed using the XLSTAT© software (procedures: Grubbs test for outliers, Similarity/Dissimilarity matrices, Discriminant analysis, Canonical correlation analysis).

3. Results and Discussion

3.1. Differentiation of Iberian Fattening Production

Results of the canonical discriminant analysis based on technical and environmental variables are presented in Table 3. The most discriminating variables between the fattening types implemented in Iberian pig farms are noted in **Table 3**. From technical variables studied, the most discriminant variables were "LU value", "*Dehesa* land use", and "Sows". Regarding the second component of the analysis, related to environmental variables, the most discriminant variables were "GW value" and "GW". Considering both sets of variables together, those variables with a greater discriminant ability were "LU value", "GW", and "GW value".

Differences between fattening management types were observed in technical variables (**Table 3**). The most important and significant difference between Iberian farms is found in "*Dehesa* land use", influencing in the fattening management. "*Dehesa* land use" increase the natural resources availability when this technical variable moves to higher values. For this reason, MF showed higher "*Dehesa* land use" compared to DF and it is explained by the higher percentage of fatteners' acorn and grass-fed during the finishing period. In other technical variables, no significant differences were found due to the great variability shown on DF data. Nevertheless, the different types of Iberian farms can be characterized through the results obtained. While MF produces higher *montanera* meat production per *dehesa* hectare, DF obtains a greater pig meat production per hectare. A higher meat production in DF is achieved to a higher pig stocking rate that characterizes the intensification of this type of farm system. On DF, the production of pigs through the two coexistent types of fattening (*montanera* and *cebo de campo*) and a higher number of sows both finally increase the pig stocking rate. In contrast, the legal requirement of several hectares of *dehesa* for animal feeding purposes reduces the pig stocking rate in MF. The combined condition of a greater number of animals as an output together with a lower "*Dehesa* land use" lead DF towards dependence on compound feed because of lower natural resource availability per animal produced. Because of this feed dependency, feedstuffs inputs per hectare are 3.5 times superior on DF than on MF in this study.

Table 3. Results of canonical discriminant analysis with technical and environmental variables.

Variable	*Montanera* Farms (MF)	SE [1]	Diversified Farms (DF)	SE[1]	Wilks' λ	F-value	*p*-value	CAN [2]
Technical variables								
Farm surface	658.6	132.4	577.7	171.9	0.996	0.13	0.720	0.088
Dehesa land use *	87.17	4.89	63.42	11.75	0.875	4.87	0.034	0.606
Pig stocking rate	0.09	0.02	0.16	0.05	0.950	1.79	0.190	−0.419
Sows *	0.06	0.01	0.37	0.29	0.936	2.33	0.014	−0.349
Piglets output	1.30	0.21	1.86	0.37	0.945	1.98	0.168	−0.305
kg *montanera*	113.5	24.36	60.02	13.13	0.939	2.22	0.145	0.339
kg total pig production	97.06	16.07	125.4	43.02	0.984	0.56	0.458	−0.371
ha value	291.2	48.71	312.1	92.05	0.999	0.49	0.826	−0.346
LU value *	2825.5	72.49	2012.0	186.3	0.586	24.06	<0.001	0.962
Feedstuffs inputs	115.9	43.52	406.3	262.9	0.938	2.25	0.142	−0.152
Environmental variables								
GW *	3.41	0.05	4.44	0.27	0.570	25.66	<0.001	−0.953
LO	43.00	4.70	30.15	4.59	0.919	3.00	0.09	0.492
GW value *	0.88	0.01	0.63	0.06	0.486	36.00	<0.001	0.989
LO value	0.09	0.01	0.11	0.01	0.951	1.76	0.193	−0.376

[1] SE: standard error. [2] CAN: correlation of each variable with the canonical function. LU: livestock unit; GW: global warming; LO: land occupation. * Most discriminating variables between fattening types.

Table 4. Discriminant canonical models for technical and environmental variables.

Model	Variables in the Model	Number of Groups	Wilks' λ	F-Value	*p*-Value
Technical	Sows, Value LU	2	0.474	18.30	<0.001
Environmental	LO, Value GW	2	0.425	45.36	<0.001
Both sets	Value LU, Value GW	2	0.411	35.99	<0.001

Environmental differences were observed between Iberian farms (**Table 3**) majorly caused by the management described previously. Intensification of livestock production increases the inclusion of concentrated feed in the diet and decreases the grazing period, causing negative environmental impacts (Zucali et al., 2020). From LCA, "GW" is lower on MF than DF which indicates that a greater use of natural resources in MF is the best measure for reducing the environmental impacts on livestock activities (Espagnol & Demartini, 2014; García-Gudiño et al., 2020; Monteiro et al., 2019), since a high number of animals per unit limit the availability of natural resources increasing the consumption of compound feed on DF. In contrast, LCA shows a trend towards greater "LO" in MF than DF. The trend might correspond to the attachment of natural resources on *montanera* that requires a higher area requirement for feeding animals versus a lower land requirement in *cebo de campo* (feedstuffs inputs).

Economic differences were observed between the participant Iberian farms (**Table 3**). The relationship between the economic value generated and technical variables indicates that MF obtains higher income per livestock unit (LU value). The higher income per livestock unit in MF is due to a higher price of fatteners *montanera* in the market compared to other fatteners pigs in other livestock systems around the globe (Faure et al., 2019; Szyndler-Nędza et al., 2019). In addition, the economic value obtained for 1 kg CO_2 emitted (GW value) in MF is higher than in DF because MF is based on natural local resources use with the ultimate result of a reduction in GHG emissions (García-Gudiño et al., 2020).

3.2. Reference Points in Iberian Fattening Production

The canonical discriminant models obtained from the stepwise discriminant analysis based on technical and environmental variables are presented in **Table 4**. In both sets of variables, the extracted canonical functions significantly discriminated between the two types of fattening farms (MF vs. DF; $p < 0.001$, Hotelling's T2 test). The F-statistics revealed a higher discriminating ability for variables related to environmental performance. **Figure 1** also allows seeing the higher variability in DF than MF which seems reasonable due to the different types of animals produced. This outcome is supported by the Mahalanobis distances among farm groups (**Figure 2**). The Mahalanobis distances among MF and DF were 2.10 for technical variables, 2.16 for environmental variables, and 2.46 for both sets. Therefore, the two fattening types studied are distanced because all pairwise distances were significant (Miles et al., 2020).

Discriminant analysis classified the fattening farms on a preassigned group according to the selected technical or environmental variables (**Table 5**). The model based on technical and structural variables classified 83.3% of the farms correctly, and the model based on environmental variables correctly classified 97.2% of the participant farms. In addition, 85.7% of classification errors occurred on technical variables, while there was only one misclassification regarding environmental performance. These results indicated that the set of environmental variables discriminate much better than the set of technical variables the differences in management among the two different fattening types. The model based on technical and environmental variables showed a predictive ability equal to that of the model based only on environmental variables. Therefore, the set of environmental variables can be used as reference points to classify the types of fattening carried out on Iberian farms.

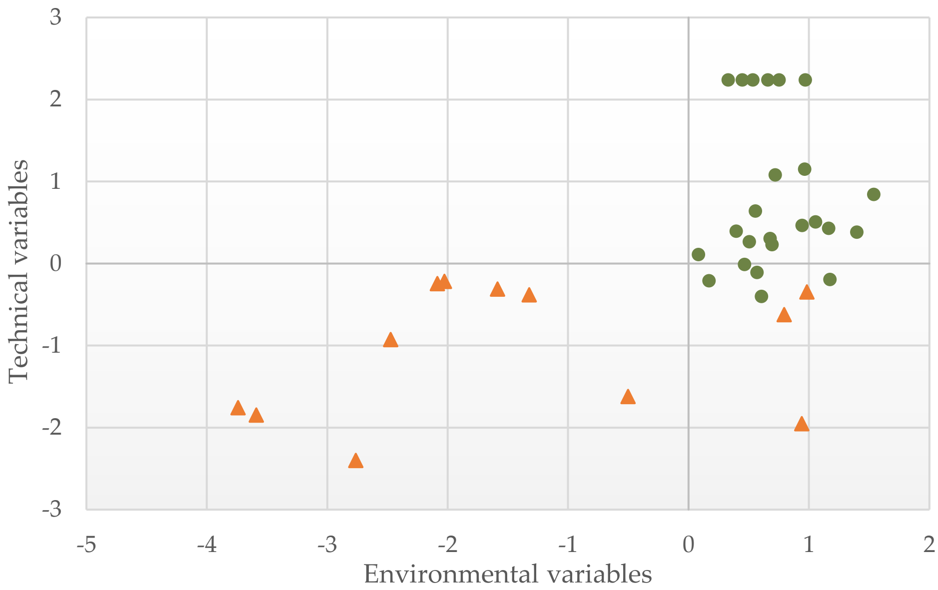

Figure 1. Graphic representation of the results from canonical discriminant analysis for technical and environmental variables, defined by the axes of the first canonical variables (orange triangle-Diversified farms; green spot-*Montanera* farms).

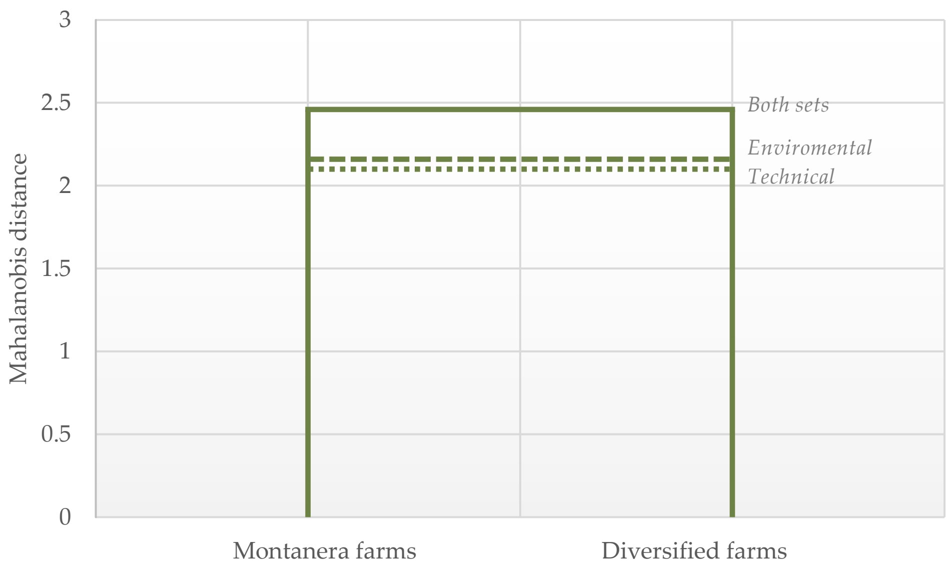

Figure 2. Dendrogram showing technical and environmental variables relationship between Iberian farms.

Discriminant analysis classified the fattening farms on a preassigned group according to the selected technical or environmental variables (**Table 5**). The model based on technical and structural variables classified 83.3% of the farms correctly, and the model based on environmental variables correctly classified 97.2% of the participant farms. In addition, 85.7% of classification errors occurred on technical variables, while there was only one misclassification regarding environmental performance. These results indicated that the set of environmental variables discriminate much better than the set of technical variables the differences in management among the two different fattening types. The model based on technical and environmental variables showed a predictive ability equal to that of the model based only on environmental variables.

Therefore, the set of environmental variables can be used as reference points to classify the types of fattening carried out on Iberian farms.

Table 5. Assignation percentages in the predefined groups and classification errors.

Group	Montanera Farms (MF)	Diversified Farms (DF)
Technical model		
Montanera farms	95.83	4.16
Diversified farms	41.66	58.33
Level of error	0.18	0.13
Prior probability	0.50	0.50
Environmental model		
Montanera farm	100.00	0.00
Diversified farm	8.33	91.66
Level of error	0.04	0.00
Prior probability	0.50	0.50
Both sets of variables		
Montanera farm	100.00	0.00
Diversified farm	8.33	91.66
Level of error	0.04	0.00
Prior probability	0.50	0.50

Results obtained from canonical correlation analysis are presented in **Table 6**. The model extracted 58.52% of the variance from the set of structural and technical variables, and 100% of the variance for the set of environmental variables. Canonical correlations for the first and second pair of canonical variables were 0.973 and 0.844, respectively. These values were significant and represented 69.24% of the variability observed in the model.

Table 6. Canonical correlation analysis on technical and environmental variables.

Factor	Eigen Value	Canonical Correlation	Variability, %	Wilks' λ	p-Value
F1	0.946	0.973	39.49	0.006	<0.001
F2	0.712	0.844	29.75	0.104	<0.001
F3	0.559	0.748	23.36	0.362	0.032
F4	0.178	0.421	7.40	0.822	0.615

The correlation structure (**Figure 3**) showed that environmental performance was strongly correlated with land use, degree of intensification, and feeding practices. The first pair (F1) of canonical variables linked environmental values with land use and degree of intensification (**Figure 3**), showing that a more intensified fattening system generates a higher economic yield per hectare. The main cause of higher profitability is the increase in the number of animals produced. The production of fatteners *cebo de campo* is carried out in a lower area (15 fatteners pigs per hectare) as stated in the legislation (Real Decreto 4/2014), increasing the number of animals by area on more intensive management (Espagnol & Demartini, 2014). To improve profitability, Iberian farms can produce various production cycles of fatteners on *cebo de campo* per year. In contrast, Iberian farms with the exclusive production of fatteners in *montanera* only could fit one productive cycle per year as the ability of the Iberian pig breed to feed on acorns is possible from October to March (Benito et al., 2006). Consequently, a greater number of productive cycles in *cebo de campo* increases the economic value per hectare.

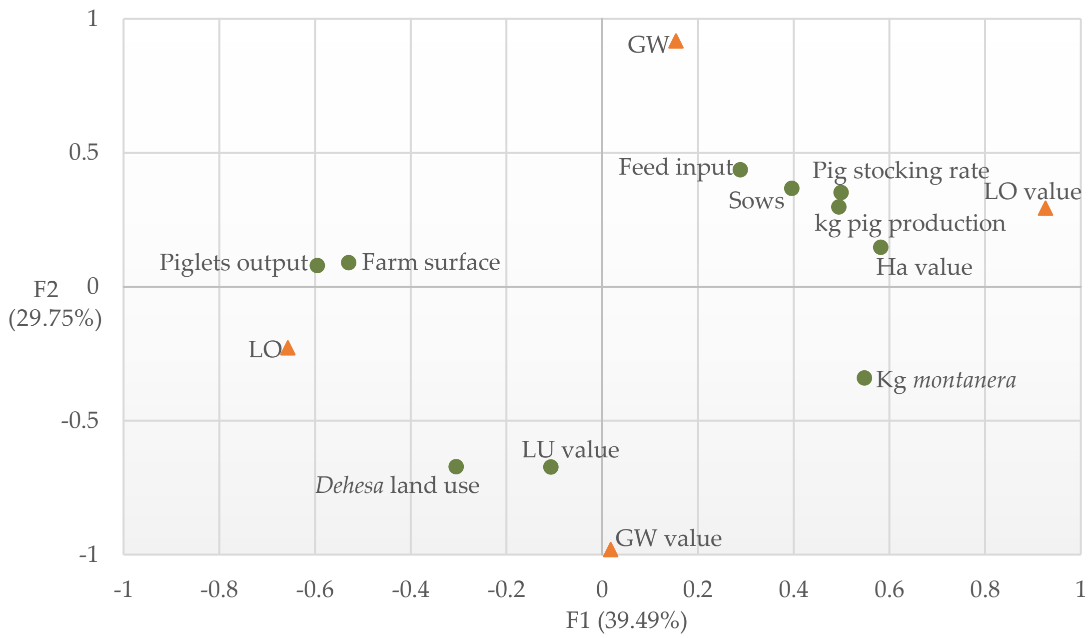

Figure 3. Canonical correlation analysis similarity map determined by the first and second canonical variables for technical (green spot) and environmental variables (orange triangle).

The second pair (F2) of the canonical variables linked environmental variables with feeding practices (**Figure 3**). The best practice to reduce emissions is to increase the proportion of natural resources in animal feeding (García-Gudiño et al., 2020) and to reduce the use of imported feedstuff. For reaching this goal, the fattening systems must optimize the use of the resources of the *dehesa*. As a result, the ratio of fatteners *montanera* in relation to the number of animals produced would increase the feeding through natural resources base. The predominance of fattening *montanera* together with a better price of fatteners *montanera* in the market increases "LU value" in Iberian farms where fatteners *montanera* are produced. Consequently, Iberian farms with a lower production of emissions generate more economic value per environmental unit emitted. According to our results and interpretations, the first combination of standardized canonical variables could be considered a predictable measure of LO, and the second combination could be considered a predictable measure of GW.

The fattening management per se determines the economic and environmental characteristics of the farm unit. MF is more environmentally friendly due to extensive fattening management focused on better use of the *dehesa*'s natural resources (Rodriguez-Estevez et al., 2012). DF is more profitable due to a more intensive management in the fattening period, increasing the stocking rate and feedstuffs inputs. This interpretation is in line with other studies on Iberian pig production (Rodriguez-

Estevez et al., 2012) which contributes to show sample representativeness of the participant farms in this study.

3.3. Improvements for More Sustainable Iberian Fattening Production

Through the results obtained in the present study, it is possible to elaborate strategies focused on the improvement of the sustainability of the Iberian pig sector in the *dehesa*. Based on the optimal economic and environmental results obtained by the MF, the Iberian pig traditional livestock should be oriented towards the production of finishing pigs in *montanera* as a first option. The reason is mainly based on the environmental values obtained for the close attachment to natural resources during fattening *montanera* (García-Gudiño et al., 2020).

The reduction of inputs required by making more efficient use of internal resources can improve the environmental sustainability of livestock activity (Martin et al., 2020). For this reason, the MF can be more environmentally sustainable through the optimization of the resource-use of the *dehesa* ecosystem. The MF should maximize "kg *montanera*" through increased fatteners *montanera* stocking rate in the *dehesa* during the finishing period, still under the framed legislation. To achieve this goal, the reforestations are necessary to increase the number of fatteners *montanera* that are produced. According to Spanish legislation (Real Decreto 4/2014), the farm unit could increase from 0.25 to a maximum of 1.25 fatteners *montanera* per hectare depending on the woodland density. As a result of this improvement, the "kg *montanera*" would increase while "LO" per kg of live weight at farm gate would decrease (Dourmad et al., 2014). This way, increased efficiency generates both an improvement in livestock and environmental performances (Zucali et al., 2020).

Although the finishing period in *montanera* should be the first option for fattening pigs, the *cebo de campo* fattening is necessary for several reasons in Iberian traditional pig production at present. For instance, the *cebo de campo* fattening is a valid alternative for the overproduction of piglets that exceeds the capacity of the *dehesa* to fatten pigs with natural resources only (Mesías et al., 2009). In this way, the surplus of piglets is not converted into an undesirable output. If the *cebo de campo* was more linked to the land, the feed inputs required would have been reduced (Martin et al., 2020). This is a more favorable scenario since feed production is the main hotspot for several environmental impacts (González-García et al., 2015; Monteiro et al., 2019; Zucali et al., 2020). For this reason, adapting feeding strategies and animal management can reduce, to some extent, the environmental impacts (Cadéro et al., 2020) of the Iberian traditional pig production. The good management practices can be carried out during the phases of growing and fattening because the Iberian pigs are fed with compound feed and natural resources in both phases.

The results showed that DF consumes 3.5 times more feedstuffs inputs than MF. A decrease in compound feed consumption reduces the environmental impacts resulted from feed production (Dolman et al., 2012). For that purpose, optimal use of pasture is an appropriate feeding strategy for extensive systems since outdoor pigs obtain a considerable portion of nutritional requirements from grazing, reducing the daily ration (Monteiro et al., 2019). Furthermore, the integration of pig production into cereal crops is possible (Quintern, 2005). Iberian pigs can graze the cereal crop before the earing phase (Gil et al., 2008), and the harvested grain can be used as additional feed for Iberian pigs, reducing the number of feed inputs. Another feeding strategy to improve the sustainability of pig production is the use of local feed products (Van Der Werf et al., 2005). For instance, some authors (Ali et al., 2017; Mackenzie et al., 2016; Monteiro et al., 2019) investigated the use of local subproducts in swine feed, quantifying a reduction of environmental impacts. In addition, the use of local protein sources in feed production such as sainfoin (Baldinger et al., 2014), grain legumes (González-García et al., 2015), or rapeseed (van Zanten et al., 2018), among other alternative sources (Florou-Paneri et al., 2014) showed a reduction of the environmental impact of different pig systems and geographical contexts.

4. Conclusions

In the conditions of the present work, it is possible to conclude that the Iberian pig production located in the *dehesa* ecosystem shows a great differentiation in technical and environmental aspects according to the type of fattening. The results show that the relationship between technical and environmental variables is strong. Due to this relationship, the classification of Iberian farms according to the type of fattening is possible through environmental variables in a more precise manner.

In the Iberian pig production located in the *dehesa* at present, the two concurrent types of fattening are necessary and complementary. While the fattening *montanera* optimises the use of the natural resources offered by the *dehesa*, being a more eco-friendly livestock production, the fattening *cebo de campo* permits the fattening phase to be carried out when acorns are not seasonally available, resulting in a more profitable pig production. The combined use of fattening *montanera* and *cebo de campo* is the optimal fattening strategy to improve the sustainability in Iberian traditional pig production.

In order to improve the sustainability in Iberian traditional pig production, environmental impacts of these systems may need to be mitigated by good management practices. Further investigations are needed to explore strategies that focus on reducing environmental impacts and increasing profitability at the Iberian farms.

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Capítulo cuarto

Targeting environmental and technical parameters trough eco-efficiency criteria for Iberian pig farms in *dehesa* ecosystem

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Targeting environmental and technical parameters through eco-efficiency criteria for Iberian pig farms in the *dehesa* ecosystem

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Abstract: Eco-efficiency could be defined as the simultaneous ability to achieve economic results with the least possible environmental degradation. Its analysis in crop and livestock production systems has become a hot topic of in-depth debate among politicians and scientists. Pig production systems reared on pasture are in high commercial demand because they are associated with high quality and environmentally friendly products. This work aimed to assess the eco-efficiency of pig farms and subsequently explore the determinants of inefficiency in the *dehesa* ecosystem in the southwest of the Iberian Peninsula. Farmers from 35 randomly selected farms were interviewed to obtain farm-level data for the 2016-2018 production periods. The eco-efficiency level was calculated through a joined Data Envelopment Analysis - Life Cycle Assessment (LCA) approach. Subsequently, a truncated Tobit model was applied to determine factors associated with inefficiency. The results of the research revealed that Iberian pig farmers are highly eco-efficient. The estimated average eco-efficiency score is 0.919, suggesting that the average farm could increase its value by about 8.1%. This means that the aggregate environmental pressures could be reduced by approximately this proportion (8%) while maintaining the same input level. The eco-efficiency level of the sample farms ranged from 0.479 to 1 (average 0.92). The determinants related to social and demographic characteristics that positively affected eco-efficiency were the number of children, while years of farm activity and educational level had a negative effect. On the other hand, farm's characteristics and the type of management, the percentage of own surface area, the percentage of livestock use, and the high proportion of pigs fattened in *montanera*, positively affected the eco-efficiency level.

Keywords: eco-efficiency, sustainability, Iberian pig, environmental impact, DEA-LCA approach.

1. Introduction

Currently, reducing the environmental impact in the primary sector while maintaining a high level of production has become an issue of special interest worldwide. For this reason, numerous initiatives have been jointly launched among EU member states, such as the Green Deal that was presented by the European Commission past December 2019 (European Commision, 2019). The Green Deal constitutes a new growth strategy aimed at transforming the EU into an equitable and prosperous society, with a modern, resource-efficient and competitive economy, in which there will be net zero emissions by 2050 and economic growth will be decoupled from natural resource use. The Farm to Fork Strategy is at the heart of the Green Deal. It aims to reduce the environmental footprint of food systems and to ensure food security to create a circular economy (European Commission, 2020). Besides, in 2015 the UN approved the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs), ranging from the elimination of poverty to combating climate change, education, women's equality, environmental protection and the design of our cities. One of goals (SDG 12) is “to ensure sustainable consumption and production patterns”, where one of the targets is to achieve sustainable management and efficient use of sustainable resources by 2030 (Cortés et al., 2021; United Nations, 2018). In this context, achieving more sustainable crop and livestock production involves bringing together different approaches within the sustainable production system – and its economic, environmental and social pillars (Kloepffer, 2008). Concepts such as eco-efficiency, which can be defined as the simultaneous ability to achieve economic outcomes with the least possible degradation of the environment, have become a highly relevant issue in the scientific and political world (Stępień et al., 2021). Livestock activities are essential to society by supplying food, supporting rural populations and contributing to the enhancement of biodiversity (Martinsson & Hansson, 2021). Therefore, the search for techniques to improve the sustainability of livestock systems should be considered an essential pivotal process in all public policies at local, national and global levels, in an attempt to address the different aspects of sustainability.

A key indicator of the optimisation of resources in agricultural systems is the assessment of technical efficiency, which measures the capacity of production units to generate the maximum level of output from the optimal use of resources or inputs. The measurement of technical efficiency is mainly based on two approaches: on the one hand, the parametric methodology that includes the construction of a stochastic (Areal et al., 2012) or deterministic frontier (Angón et al., 2013; P. Toro-Mujica et al., 2011; Paula Toro-Mujica et al., 2015); and, on the other hand, the non-parametric methodology. Currently, the assessment of technical efficiency using the non-parametric approach has been carried out using the Data Envelopment Analysis (DEA) method that uses linear programming to calculate an envelope or frontier from the available data of a set of production units (DMU; Decision Making Unit), so that the envelope is determined by the efficient units, while those that are not found in the envelope are considered inefficient (Angón et al., 2015; Li et al., 2017; Saiyut et al., 2019).

On the other hand, the growing concern for cleaner products, production and services has led organisations and companies to pursue more sustainable methods. As a consequence, several methodologies have been developed to assess the environmental impact of products, with Life Cycle Assessment (LCA) standing out in livestock production systems in order to determine the environmental impact associated with production (García-Gudiño et al., 2020). DEA was developed by Charnes et al., (1979) and is widely used to estimate relative efficiency and apply benchmarking or best practice adoption techniques (Chang & Mishra, 2011). It can be combined with LCA methodology resulting in the eco-efficiency methodological framework, which is receiving great interest as a sustainability indicator because it jointly assesses the environmental pressure of the system and the technical-economic performance of the production activity (Godoy-Durán et al., 2017). The main advantage of combining DEA and LCA in the same methodological framework is that it allows the simultaneous optimisation of the environmental impact and production performance of a production system through competitive benchmarking processes. In other words, this approach provides reference pairs according to eco-efficiency criteria for the set of farms that are part of the production system (Rebolledo-Leiva et al., 2019). However, DEA has limited use for identifying the drivers of inefficiency (You & Zhang, 2016). This problem has usually been solved by performing a further analysis with a deeper exploration of the factors hypothesised to be related to inefficiency using Tobit models or truncated regression techniques (García-Cornejo et al., 2020; Godoy-Durán et al., 2017; Li et al., 2017).

Whether at local or national level, the measurement of eco-efficiency has often been used in studies of sustainability and competitiveness improvement, both at company and sector level. Studies stand out especially with regard to the industrial sector (Gómez et al., 2018; Stergiou & Kounetas, 2021; Yang et al., 2015; Zhang et al., 2008), on farms (Chancharoonpong et al., 2021; Godoy-Durán et al., 2017; Gómez-Limón et al., 2012; Picazo-Tadeo et al., 2011; Pishgar-Komleh et al., 2020; You & Zhang, 2016) and to livestock or mixed farms (Cortés et al., 2021; García-Cornejo et al., 2020; Iribarren et al., 2011; Lozano et al., 2009; Martinelli et al., 2020; Martinsson & Hansson, 2021; Stępień et al., 2021). Environmental impact assessment studies have been carried out in traditional pig systems (García-Gudiño et al., 2020, 2021a; Horrillo et al., 2020; Monteiro et al., 2019) but there are no studies where economic results are maximised with the least possible impact on the environment.

There is an area in the southwest Iberian Peninsula known as the *dehesa*, being an agro-silvopastoral system based mainly on livestock farming, as well as agriculture and forestry, in areas of Mediterranean pastures. The interactions of these activities foster a high environmental value in which the combination of management promotes important environmental values such as sustainable land use, a balanced landscape and high levels of diversity at different levels of integration (BOJA, 2006; Gaspar et al., 2009; Horrillo et al., 2020; Sánchez-Martín et al., 2019). *Dehesa* is one of the largest managed agroecosystems in Europe that represents over a million hectares. This agroecosystem is characterized by the extensive grazing of different livestock species, with the Iberian pig being the native breed most closely linked to this area (Gaspar et al., 2009; Horrillo et al., 2020; Rodríguez-Estévez et al., 2009; Sánchez-Martín et al., 2019). The Iberian pig in the *dehesa* is reared extensively and uses natural resources such as acorns and pasture (**Figure 1**). *Dehesa* represents the highest concentration of production and supply of Iberian pig sector in the European Union. In recent decades, the demand for pigs raised in extensive production systems has grown due to the association of these production systems with high-quality and environmentally friendly meat products (Eldesouky et al., 2020; García-Gudiño et al., 2021b). For this reason, the *dehesa* is currently suffering an alarming environmental situation due to the great stress exerted on its natural resources (Horrillo et al., 2020). Nowadays, it is a great challenge for society and for achieving sustainability to find a balance between economic performance and the use of natural resources. Therefore, it is not only important to evaluate indicators of eco-efficiency and their production and environmental pressure reduction targets, but it is also crucial to analyse the factors that could influence the reduction of these pressures. In particular, the study at the farm level is of interest, as the traditional pig sector is characterised by a large number of small-scale farms with certain heterogeneity.

Figure 1. Herd of Iberian pigs reared on the *dehesa***.**

This study follows an LCA-DEA approach to measure the eco-efficiency of extensive pig production in the Spanish *dehesa* and pursues two objectives, (i) using the LCA-DEA approach to calculate the level of eco-efficiency and (ii) to analyse the determinants of inefficiency using Tobit regression analysis. Social, demographic and structural characteristics of pig farms are analysed as potential causes of inefficiency. This study is the first to apply this methodology to the Iberian pig sector raised in the *dehesa*. Understanding the key determinants that lead to inefficient production units will be beneficial for improving productivity and competitiveness, as well as for promoting a more sustainable livestock production.

2. Material and methods

2.1. Study area and data collection

The study was carried out in the traditional area of Iberian pig production, which takes place in the agroecosystem called *dehesa*. Data were collected through face-to-face questionnaires from 35 Iberian traditional farms as described elsewhere by García-Gudiño et al. (2020). Data achieved for this study were farm area, structural and productive data, economic and management aspects, information about other activities (agriculture and livestock), personal issues and labour aspects.

Environmental variables employed were derived from García-Gudiño et al. (2020). The impacts of Iberian pig production considered were climate change ILCD (CC, kg CO_2 eq) and land occupation (LO, m^2.year). The functional unit was one kilogram of live weight at the farm gate. LCA were performed by Simapro software (version 8.5.2.0, PRé Consultants, Amersfoort, The Netherlands).

2.2. LCA-DEA approach and Tobit model

In this study, we propose a four-step approach that estimates on the one hand the environmental impact on CC for each DMU's and subsequently includes it as an undesirable output in the DEA model in order to determine the environmental impact reduction. This approach is based on an adapted version of the four-step method used by Rebolledo-Leiva et al. (2017) and (Angulo-Meza et al. (2019). A step-by-step schematic of the procedure is shown in **Figure 2.**

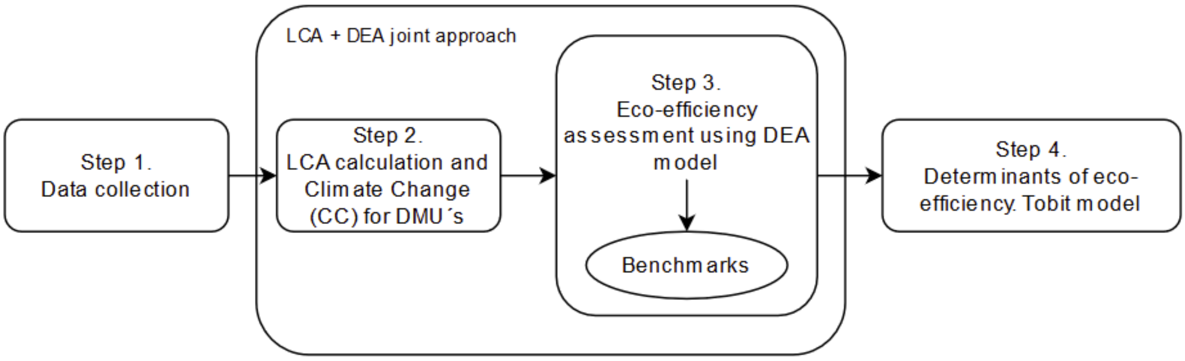

Figure 2. Four-step LCA- DEA and Tobit model (adapted by Rebolledo-Leiva et al. (2017) and Angulo-Meza et al. (2019)).

The study presented by García-Gudiño et al. (2020) calculates the environmental variables to be used as indicated above. Subsequently, in our study, the evaluation of eco-efficiency is estimated by means of a multi-objective DEA model oriented to the value of pig production (€/year) that minimizes the undesirable output, that is the environmental impact on climate change (CC, kg CO_2 eq). The model based on Variable Returns to Scale (VRS) assumption considers the differences in size and scale of the producers, as proposed by Lozano et al., (2009). Moreover, most production systems operate under this assumption as indicated by Coelli et al. (2005).

The use of DEA methodology allows identifying best practices or benchmarks (often two or more peer references) for each inefficient DMU, as well as new levels of production and CC; and necessary changes in input or resource levels. As the targets are defined by these benchmarks, the inefficient DMU must follow its best operational/management practices to achieve the target in order to reach an eco-efficient state (Angulo-Meza et al., 2019). All targets are positioned on the efficient frontier; such as if inefficient DMUs achieve one of their alternative targets, it will become efficient. The model, which considers VRS assumption and its constraints, can be presented as the following:

$$\text{Max } \emptyset_1$$

$$\dots$$

$$\text{Max } \emptyset_s$$

$$\text{Min } \emptyset_1$$

$$\dots$$

$$\text{Min } \emptyset_m$$

Subject to

$$\sum_{j=1}^{n} y_{rj}\, \lambda_j \;\geq\; \emptyset_r\, y_{r0};\ \forall\, r = 1, \dots, s$$

$$\sum_{j=1}^{n} x_{ij}\, \lambda_j \;\leq\; \emptyset_i\, y_{i0}\,;\ \forall\, i = 1, \dots, m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\emptyset_r \geq 1;\ \forall\, r = 1, \dots, s$$

$$\emptyset_i \leq 1;\ \forall\, i = 1, \dots, m$$

$$\emptyset_r\ \emptyset_i, \lambda_j \geq 0$$

Where m is the input, s is the output and n DMUs, x_{ij} is the input i of DMU j, i = 1,….,m; y_{rj} is the output r of DMU j, r = 1,…,s, with j = 1,…,n; λ_j is the contribution intensity of best practice or benchmark j to the DMU target under evaluation. Increasing outputs ($\emptyset_r$) and decreasing inputs ($\emptyset_i$) are optimised, while constraints ensure that these new levels are on the eco-efficient frontier. The constraint $\sum_{j=1}^{n} \lambda_j = 1$ guarantees VRS of the model.

Finally, the last stage of the process is carried out to analyse which factors determine inefficiency, or lack of eco-efficiency once it is found to exist. The aim is to find out why some production units are more efficient than others. Numerous studies show that the most common explanation is that there are differences in social and structural aspects, as well as in management capacity and decision-making processes (García-Cornejo et al., 2020; Godoy-Durán et al., 2017; Li et al., 2017; You & Zhang, 2016). For Ceyhan et al. (2017) the appropriate regression when using the level of eco-efficiency as the dependent variable is a Tobit regression.

The Tobit model, also called censored regression model, is used to estimate linear relationships between variables when there is left or right censoring in the dependent variable. The model is defined as follows:

$$\text{EE} \geq \beta X_k + \varepsilon_k$$

Where EE is each calculated eco-efficiency score, $\varepsilon_k \sim N(0, \sigma^2)$ and β is the vector of model parameters for the vector of explanatory variables X_k (Tobin, 1958).

In this study the Tobit model is used to analyse the effect of socio-demographic aspects of the producer (family size, civil state, age, experience, education level, UTH) and structural and management characteristics of the farm (percentage owned area, percentage small ruminant livestock units, percentage of the area used for livestock, Protected Designations of Origin (PDO), type of management and the level of *montanera* orientation on the eco-efficiency levels of the pig production system. These possible determinants of eco-efficiency were collected through face-to-face questionnaires mentioned in the Section 2.1 and are detailed in **Table 1.** The variable level of *montanera* orientation has been categorised according to the proportion of pigs fattened in *montanera*: high, medium and low. The medium level of fattening dedication was set in the range ($\bar{x} - \frac{1}{2}SD, \bar{x} + \frac{1}{2}SD$), where $\bar{x}$ is the mean value and SD is the standard deviation (Angón et al., 2013; Pérez et al., 2007).

Table 1. Definition of dependent and explanatory variables of the inefficiency used in Tobit models.

Dependent variables		**Definition of the variables**
Eco-efficiency level		*Social and demographic aspects*
	Family size	Number of family members
	Number of children	Number of children
	Civil state	Dummy = 0 (single); Dummy =1 (married)
	Age	Manager age
	Experience	Number of years of managerial experience
	Education level	Dummy = 0 (primary or without studies); Dummy = 1 (secondary studies or superior)
	AWU	Annual work unit
		Farm and management characteristics
	% owned area	Own area as a percentage of total area
	% small ruminant livestock units	Percentage of small ruminant livestock units
	% of the area used for livestock	Percentage of land area used by livestock
	PDO*	Dummy = 0 (PDO not); Dummy = 1 (PDO)
	Type of management	Dummy = 0 (intensive management); Dummy = 1 (extensive management)
	Level of *montanera* orientation	Proportion of pigs fattened in *montanera*

*PDO: Protected Designations of Origin.

All Statistical analyses were carried out with SPSS for Windows software (v.15.0, SPSS Inc., Chicago, IL) while the program used to calculate the DEA model was the deaR package version 1.2.1 for R (Coll-Serrano et al., 2018). Finally, Eviews version 11 was used to determine the censored regression model, known as the Tobit model.

3. Results and discussion

3.1. Description of the Iberian pig production system

The results show that the main activity of the farms is the fattening management, based on the use of acorns and other natural resources of the *dehesa*, although there was a high variability in the data in terms of surface area, number of breeders and number of pigs produced (**Table 2**). This variability is due, on the one hand, to the fact that the volume of pig production is linked to the area of available *dehesa*. On the other hand, the variability in the number of sows reflects the different intensity, with which breeding is practised, from full-cycle farms that exclusively fatten the piglets produced, although with different intensities of use of the pasture, to farms where the supply of piglets for other farms is a management goal (García-Gudiño et al., 2021a). The data obtained in terms of surface areas and pig censuses are close to other studies carried out in the *dehesa* ecosystem (Gaspar et al., 2008; Horrillo et al., 2020; Rodríguez-Estévez et al., 2009).

Table 2. General information of the participant Iberian pig farms (n=35).

Variable	**Mean**	**SD**	**Min.**	**Max.**
Total surface	646.4	627.0	28.5	3,000
Surface of *dehesa*	498.0	437.8	18	2,000
% Surface used of *dehesa*	84.00	25.89	0	100.0
Number of sows per farm	27.60	25.75	0	100.0
Number of reproductive males per farm	0.89	1.08	0	4.20
Number of piglets fattened per farm	319.7	315.0	0	1260
CC* (kg CO_2 eq./kg LW)	3.70	0.69	2.87	6.07
LO* (m^2·year/kg LW)	39.42	21.49	13.83	126.0

*SD: Standard deviation; CC: Climate Change; LO: Land Occupation

Regarding CC, the data obtained indicate that Iberian pig production is close to other traditional pig production (Dourmad et al., 2014), but it has greater LO impacts than other traditional pig breed systems (Dourmad et al., 2014; Monteiro et al., 2019). It could be mainly explained by the large surface area required for fattening animals fed exclusively on natural resources from the *dehesa* (Real Decreto 4/2014).

3.2. Eco-efficiency assessment using LCA-DEA approach and Tobit model

3.2.1. Variables

The multi-objective DEA model is built from two inputs and two outputs (**Table 3**). As inputs, the use of surface area and number of reproductive females were chosen because they are main control factors with effects on eco-efficiency, according to the characteristics of the Iberian pig production developed in the *dehesa* (Horrillo et al., 2020). As outputs, the porcine production value was used, including the main product and by-products of each pig sold. The environmental impact on CC was calculated by García-Gudiño et al. (2020) through the LCA methodology also considering previous literature (Angulo-Meza et al., 2019; Li et al., 2017).

Table 3. Variables used in the Data Envelopment Analysis (DEA) model (n=35).

	Outputs		Inputs	
	Production value (€)	**Climate change (CC, kg CO_2-eq/kg LW)**	**Surface in *montanera***	**Number of sows**
Mean	129,338	3.70	498.7	27.60
SD*	112,458	0.69	442.7	25.75
Minimum	13,502	2.87	0	0
Maximum	634,500	6.07	2,000	100.0

*SD: Standard deviation

The selection of inputs and outputs in the approach has been performed in order to synthetically reflect the pig production process developed in the *dehesa*. In addition, previous studies have been taken into account to analyse the eco-efficiency of agricultural and livestock enterprises (Angulo-Meza et al., 2019; Cortés et al., 2021; García-Cornejo et al., 2020; Godoy-Durán et al., 2017; Iribarren et al., 2011; Li et al., 2017; You & Zhang, 2016). Furthermore, the rule shown by Cooper et al. (2011) has been considered in order not to excessively limit the degrees of freedom of the model. The recommendation is to select a value of *n* that satisfies n ≥ {m x s; 3(m + s)} where *n* is the number of DMUs (35 pig farms in this study), *m* is the number of inputs, and *s* is the number of outputs. Therefore, the number of DMUs in our sample satisfies the rule in this study and the requirements for this methodology were met.

3.2.2. Eco-efficiency results

The multi-objective DEA model for an Iberian pig farm (DMU) is presented as following:

$$\text{Max } \emptyset_V$$

$$\text{Min } \emptyset_{CC}$$

Subject to

$$\sum_{j=1}^{n} y_V \, \lambda_j \geq \emptyset_V \, y_V$$

$$\sum_{j=1}^{n} y_{CC} \, \lambda_j \leq \emptyset_{CC} \, y_{CC}$$

$$\sum_{j=1}^{n} x_M \, \lambda_j \leq x_M$$

$$\sum_{j=1}^{n} x_S \, \lambda_j \leq x_S$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\emptyset_V \geq 1$$

$$\emptyset_V \leq 1$$

$$\emptyset_{V,} \emptyset_V, \lambda \geq 0$$

Where the inputs correspond to surface area in *montanera* (M) and number of sows (S), and the outputs correspond to the economic value of pig production (V) and environmental impact on CC. A VRS model is assumed to consider differences in size and scale.

This model has two objectives, on the one hand, the economic value of pig production is maximised, while the undesirable output of CC is minimised, all while keeping the level of inputs constant. There are several approaches to deal with undesirable output (CC), in Rebolledo-Leiva et al. (2017) the function to maximise includes the inverse of the undesirable output because maximising the inverse is equivalent to minimising it, while in Lozano et al. (2009) the undesirable output is treated as an input to minimise. The advantage of using independent objective functions, such like our study, is that it allows finding goals considering these two objectives at the same time: maximising the production value and minimising the environmental impact on CC (Angulo-Meza et al., 2019).

To calculate the average of eco-efficiency values and benchmark values, the DEA matrix (**Table S1** of the supplementary material) was applied in the optimisation model. **Table S1** also presents the eco-efficiency value calculated for all pig farms. On average, the Iberian pig farms in the *dehesa* showed a high level of eco-efficiency. The average estimated level was 0.919, suggesting that the average farm could decrease its environmental impact by 8% by CC given the level of inputs and production technology when farms adopt the observed best practices. The minimum and maximum eco-efficiency score was estimated at 0.479 and 1, respectively. These observed differences between the minimum and maximum values indicate a considerable degree of variation in the eco-efficiency of the *dehesa* Iberian pig systems.

These results are in line with previous studies on environmental impact assessment in pig production systems, where it is highlighted that lower environmental impacts can be achieved in pig production linked to the territory using native breeds (Horrillo et al., 2020). This is due to a lower dependence on off-farm feed due to the feeding strategic of these production systems with greater use of natural resources (Espagnol & Demartini, 2014; García-Gudiño et al., 2020; Garcia-Launay et al., 2016; Monteiro et al., 2019), such as acorns available in the meadows and pastures of the *dehesa* (Espagnol & Demartini, 2014; García-Gudiño et al., 2020; Garcia-Launay et al., 2016; Monteiro et al., 2019).

The frequency distribution of the eco-efficiency estimates obtained is presented in **Table 4.** It is evident that there is some variation in respect of the use of existing technology in terms of eco-efficiency. Fourteen of the 35 farms, i.e. 40% of the total, are fully efficient from a technical and environmental point of view, revealing that the Iberian pig farms in the *dehesa* are using the current technology in a fairly rational way in terms of management. The highest number of inefficient farms was found in the ranges 0.80 to 0.90 and 0.90 to 0.99, with nine farms each, and the lowest in the score range from 0 to 0.80 with three farms. A total of 14 farms had eco-efficiency values of 1 constituting 40% of the sample. **Figure 3** represent the distribution of mean total pig production (kg/year) and LO values according to the level of eco-efficiency achieved. Regarding **Figure 3**, we can conclude that the increase in LO implies a decrease in eco-efficiency levels. This is probably due to the increase in the number of pigs fattened with feedstuffs, thus increasing the hectares needed to produce raw materials for feed production. Another reason could be the low density of holm oaks and cork oaks, which has an impact on the surface area needed in the *montanera* (Real Decreto 4/2014). Reforestation techniques in the *dehesa* could have a positive impact on eco-efficiency levels (López-Sánchez et al., 2014).

Table 4. Frequency distribution of farms, by eco-efficiency estimates from the Data Envelopment Analysis (DEA) model (n=35).

Level of eco-efficiency	Number of farms	%	Mean
Low < 0.80	3	8.60	0.64
Medium 0.8-0.9	9	25.70	0.86
High 0.9-0.99	9	25.70	0.94
Eco-efficient*	14	40.00	1
Total	35	100.0	0.919

*Eco-efficient indicate a level of eco-efficiency of 1.

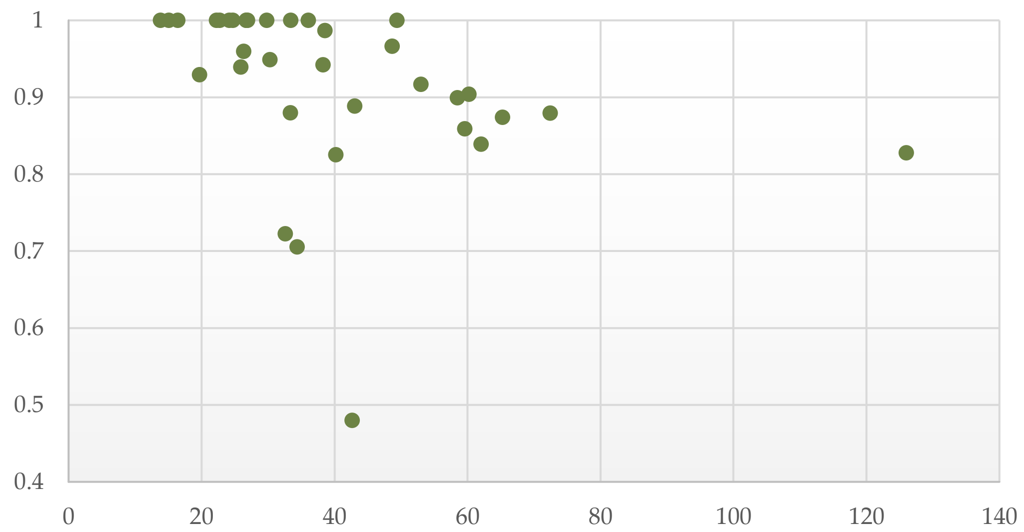

Figure 3. Eco-efficiency level (x-axis) with respect to land occupation (LO) (y-axis).

3.2.3 Targets for CC, output value and inputs for inefficient DMUs

Once eco-efficiency has been determined, targets for the variables for inefficient pig farms are calculated. The DEA model provides targets for inputs (surface area in *montanera* and number of sows), which allow reducing current CC levels while maximising the value of pig production to become eco-efficient.

Table S2 in the supplementary material presents the slack and CC reduction targets, as well as the target for increasing the value of pig production and its percentage, in relation to the original values considered in the analysis of inefficient farms.

For inefficient farms, important reduction targets are proposed. Inefficient farms if they adopt the best practices of their benchmarks can reduce the surface area in *montanera* used by 11.98 % and the number of sows by 13.54 %. On the other hand, the economic value of pig production (€/year) can be increased by 18.7% while reducing the environmental impact of CC of the system by 8.3% (**Table 5**).

Table 5. Average percentage reduction of resources, sows and climate change, and increase of production value.

Variable	**Value (%)**
Reduction percentage of surface in *montanera*	11.98
Reduction percentage of number of sows	13.54
Climatic Impact on CC* reduction	8.32
Production value increase	18.68

*CC: Climate change

The objective of reducing the area of *montanera* while achieving the same production would have a positive effect for those farms that fatten animals with acorns and feed. The surplus area of *montanera* can be used to fatten more pigs with natural resources (acorns and grass), reducing the environmental impact and at the same time increasing the income as the pigs fattened with acorns have a higher commercial value. In addition, the reduction in the number of reproductive females in inefficient farms is a fact that has been shown by other authors in the *dehesa* (Gaspar et al., 2009). This is more evident for management multi-output systems (pig fatteners *montanera*, pig fatteners *cebo campo*, piglet sales).

These projections of the analysis reveal the maximum potential for input and environmental impact reduction that can be achieved in Iberian pig production in the *dehesa*. There are no existing studies on Iberian pigs, but our sample has a better projection of improvement than other previously evaluated livestock systems with reductions of more than 30% (Cortés et al., 2021; Lozano et al., 2009; Vázquez-Rowe & Iribarren, 2015). Furthermore, what the above projections confirm is that it can be concluded that actions are needed to improve economic rather than environmental performance, due to the fact that traditional Iberian pig production systems are associated with sustainable productions based on natural resources and low environmental impact (Espagnol & Demartini, 2014; García-Gudiño et al., 2020; Horrillo et al., 2020). Possibly these actions should be aimed at decreasing dependency on external inputs such as feedstuffs. Production systems based on fattening *montaner*a produce better environmental and economic benefits (García-Gudiño et al., 2020, 2021a). On the contrary, those based on fattening *cebo-campo* produce pigs fed with great quantities of compound feed and a product of poorer commercial quality according to the Spanish regulations regarding the quality of Iberian pork products (Real Decreto 4/2014). However, assessing the economic sustainability of pig farms is a complex problem, like many short- and long-term factors are involved (Malak-Rawlikowska et al., 2021).

Besides that, the method developed in this study allows us to know the intensity (λ) of each benchmark or best practice of each inefficient pig farm, i.e. what is called benchmarking. These intensities for each inefficient DMU are presented in **Table S3** (supplementary material). **Table S3** provides guidelines for determining an improvement plan for inefficient DMUs to become efficient. The best practices in our sample are DMU 30, DMU 27 and DMU 23 that benchmark 18, 14 and 9 inefficient DMUs, respectively. These farms are characterised by traditional management. These farms are focused on the production of Iberian pigs fed on a natural resources-based diet. The number of breeders is adapted to the maximum number of Iberian pigs that can be fattened on the farm according to the size of the surface and density of trees. Reproductive management is traditional, natural mating and two farrowing per year. Breeding is carried out extensively until the *montanera* season, when the animals are fattened only with natural resources.

To illustrate this procedure, we take DMU 3 as an example. This farm has an eco-efficiency level of 0.84 and a CC target of 2.94 kg CO_2 eq. and its reference points are DMU 27 and DMU 30 with intensities of 0.1745 (λ_{27}) and 0.8255 (λ_{30}), respectively. **Table S1, S2** and **S3** show DEA matrix, inputs/outputs target and the benchmarks intensities, respectively for DMU 3 and all Iberian traditional farms.

3.2.4. Determinants of inefficiency

The effect of the factors hypothesised to influence inefficiency assessed using the Tobit model are shown in **Table 1**. The results of the regression analysis are shown in **Table 6**.

Table 6. Statistical analysis of Tobit model.

Variable	Coefficient	SE*	z-Statistic	p-value
Social and demographic aspects				
Family size	-0.002883	0.035695	-0.080764	0.9356
Number of children	**0.065596**	**0.020803**	**3.153.233**	**0.0016**
Civil state	-0.026756	0.046468	-0.575791	0.5648
Age	0.007590	0.005261	1.442.852	0.1491
Experience	**-0.011463**	**0.004038**	**-2.839.121**	**0.0045**
Education level	**-0.138727**	**0.050600**	**-2.741.620**	**0.0061**
AWU*	0.032217	0.052929	0.608680	0.5427
Farm and management characteristics				
% owned area	**0.001732**	**0.000867**	**1.996.838**	**0.0458**
% small ruminant livestock units	0.054434	0.124319	0.437859	0.6615
% of the area used for livestock	**0.005509**	**0.001689**	**3.261.379**	**0.0011**
PDO*	0.050314	0.045072	1.116.291	0.2643
Level of *montanera* orientation	**0.081780**	**0.022082**	**3.703.435**	**0.0002**
Type of management	0.084327	0.048146	1.751.482	0.0799
C*	0.079468	0.011470	6.928.203	0.0000
Log likelihood		26,723		
AIC		-1,0602		

*SE: Standard Error; AWU: Annual work unit; PDO: Protected Designations of Origin; C: Tobit model constant.

The crucial determinants related to social and demographic aspects that positively affected eco-efficiency in Iberian pig farms were the number of children, while the variable number of years of activity and educational level, contrary to expectations, affected negatively to eco-efficiency. The latter may be due to the fact that more educated owners pursue higher profitability on their farms, and thus move away from a traditional production model which, as we have found in our study, leads them to be more eco-efficient. This could also be due to the fact that experienced farmers are more reluctant to change their management habits. Li et al. (2017) indicated in a study with 773 pig farms that the years of experience and dedication to the activity had a negative effect. Also, other studies focused on agriculture indicated that a higher level of education and specialised training affected efficiency improvement (Gómez-Limón et al., 2012), although there is some controversy with the educational level, numerous studies indicated that there is a positive relationship with university education, mainly because more education may imply more adaptation to new market opportunities, distancing from a traditional production model (Lockheed et al., 1980). While other studies have found an influence of age on eco-efficiency, our model has not detected any influence.

In terms of management, the farm characteristics as the percentage of land owned, the percentage of livestock use, and the high proportion of pigs fattened in *montanera* positively affected the level of eco-efficiency. The three factors mentioned are closely related to Iberian traditional pig production in the *dehesa* where the use of natural resources is an essential factor for the development of production. There are two different types of fattening on the *dehesa*, *montanera* and *cebo de campo*. Our study shows that those farms that perform traditional management are more eco-efficient according to results revealed by Horrillo et al. (2020) and García-Gudiño et al. (2021a) mainly by optimal use of natural resources provided by the *dehesa* ecosystem.

PDO certification is a quality indicator and an instrument that reduces the asymmetry of information between producer and consumer, specifying the production system García-Gudiño et al. (2021b). Contrary to expectations, PDO had no effect on eco-efficiency as indicated by a study of García-Cornejo et al. (2020) on livestock farms in northern Spain. In our study, it could be explained by the fact that the production of Iberian pigs is already nationally regulated (Real Decreto 4/2014).

Although this method used a robust methodology to calculate eco-efficiency scores and a Tobit regression approach, the small sample size probably limited our ability to identify the most statistically significant variables. Future studies should emphasise larger samples of production units from different locations to better understand the role of other factors, such as managing, information use and decision-making process (Angon et al., 2021; Ritten et al., 2018). Despite these limitations and the sample size, our study has contributed to the existing literature, as the first study on eco-efficiency in Iberian pig farms.

4. Conclusions

In this study, an evaluation of the eco-efficiency of Iberian pig farms in the dehesa area of the Iberian Peninsula has been carried out. The application of a combined LCA and DEA methodology of Iberian pig farms based in the *dehesa* area of the Iberian Peninsula has proved to be a very valuable tool for the comparative assessment of environmental, technical and economic parameters. The Iberian pig farms in the *dehesa* showed a high level of eco-efficiency, suggesting that the average farm could decrease its climate impact given the level of inputs and production technology, provided that the farms adopt the observed best practices. The farmer's professionalism and profile influence eco-efficiency. Other farm characteristics related to natural resources use and proportion of pigs fattened in *montanera* affected the level of eco-efficiency.

The production of Iberian pigs following traditional management systems is more eco-efficient and has a lower environmental impact, increasing its impact as it moves towards a system of fattening in *montanera*. The reduction of environmental impact implies a reduction in the consumption of feedstuffs. Therefore, better management of natural resources could reduce the dependency on feedstuffs and make traditional Iberian pig production more environmentally friendly and consequently more eco-efficient.

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contribution: Conceptualization, E.A, J.P. and J.G.G.; methodology, E.A. and J.P.; formal analysis, E.A. and J.P.; investigation, E.A.; data curation, J.G.G.; writing—original draft preparation, E.A. J.P and J.G.G.; writing—review and editing, E.A., J.P., J.G.G., I.B.P. and F.G.L.

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Supplementary Material

Table S1. Data Envelopment Analysis (DEA) matrix for the complete set of farms and eco-efficiency score.

DMU*	Output desirable Production value (€/year)	Output undesirable Climate change (kg CO^2-eq/kg live weight)	Input 1. Surface in *montanera* (ha)	Input 2. Number of sows	Eco-efficiency score
1	269,568.10	3.900	600	80	0.939
2	84,268.50	2.975	230	20	1.000
3	86,872.50	3.607	700	33	0.839
4	108,018.00	3.121	550	19	0.967
5	51,287.42	6.073	0	15	1.000
6	30,577.77	3.480	200	12	0.899
7	56,029.05	4.300	200	12	0.706
8	62,689.00	5.164	300	19	0.480
9	229,056.00	3.842	1500	90	0.859
10	137,433.60	3.559	400	40	0.880
11	63,455.85	5.524	0	22	1.000
12	148,886.40	3.450	235	50	0.929
13	99,916.65	3.482	200	0	1.000
14	64,810.80	3.527	500	12	0.874
15	86,414.40	3.114	398	10	0.987
16	335,702.61	4.247	750	83	1.000
17	109,971.00	3.440	600	30	0.889
18	634,500.09	4.393	2000	100	1.000
19	98,650.04	4.155	380	22	0.722
20	70,018.80	3.619	1000	30	0.828
21	91,458.30	3.440	600	30	0.880
22	162,027.00	3.430	1492	42	0.917
23	152,970.84	3.232	80	22	1.000
24	85,896.00	3.321	550	25	0.904
25	118,819.80	3.290	480	0	1.000
26	13,502.25	3.450	18	0	1.000
27	243,040.50	3.244	600	30	1.000
28	135,022.50	3.524	340	0	1.000
29	162,027.00	3.681	400	0	1.000
30	74,051.40	2.878	300	18	1.000
31	89,935.83	3.673	360	30	0.825
32	183,630.60	3.581	960	0	1.000
33	49,667.20	3.353	130	20	0.949
34	102,327.75	3.156	270	40	0.960
35	34,358.40	3.426	130	10	0.942

*DMU: Decision making unit.

Table S2. Input/output target and operational reduction percentages for all pig farms.

DMU*	Input 1. Surface in *montanera*	Input 2. Number of sows	% de reduction Surface in *montanera*	% de reduction Number of sows	Output desirable Production value (€/year)	Output undesirable Climate change (kg CO2-eq)	% de reduction Climate change (kg CO2-eq)	% de increase Production value (€/year)
1	600	51.37	-28.63	0	286,974.19	3.70	-5.25	6.46
3	352.34	20.09	-12.91	-49.67	103,534.53	2.94	-18.44	19.18
4	374.87	19	0	-31.84	111,744.25	2.98	-4.37	3.45
6	200	12	0	0	54,074.96	3.08	-11.55	76.84
7	200	12	0	0	79,409.93	3.14	-26.91	41.73
8	300	19	0	0	130,647.22	3.09	-40.07	108.4
9	684.12	34.21	-55.79	-54.39	266,562.82	3.31	-13.77	16.37
10	400	23.63	-16.37	0	156,184.07	3.08	-13.48	13.64
12	235	23.15	-26.85	0	160,187.49	3.18	-7.97	7.59
14	360	12	0	-28	88,974.20	3.02	-14.51	37.28
15	380	10	0	-4.52	93,948.47	3.06	-1.69	8.72
17	388.18	21.53	-8.47	-35.30	123,722.20	2.99	-13.21	12.50
19	380	22	0	0	136,547.16	3.03	-26.98	38.42
20	318.71	18.75	-11.25	-68.13	84,589.71	2.90	-19.86	20.81
21	353.11	20.12	-9.88	-41.15	103,967.06	2.94	-14.45	13.68
22	482.22	25.29	-16.71	-67.68	176,696.34	3.10	-9.62	9.05
24	337.20	19.49	-5.51	-38.69	95,006.66	2.92	-11.98	10.61
31	360	20.47	-9.53	0	108,957.85	2.95	-19.58	21.15
33	130	20	0	0	120,264.83	3.15	-5.97	142.1
34	270	19.92	-20.08	0	106,597.38	2.99	-5.18	4.17
35	130	10	0	0	48,678.76	3.20	-6.52	41.68

*DMU: Decision making unit.

Table S3. Benchmarks intensities of inefficient farms.

	Benchmark intensities								
Inefficient DMU*	**λ2**	**λ13**	**λ16**	**λ18**	**λ23**	**λ25**	**λ26**	**λ27**	**λ30**
1	0	0	0.2442	0.1856	0.5702	0	0	0	0
3	0	0	0	0	0	0	0	0.1745	0.8255
4	0	0	0	0	0	0.0792	0	0.2021	0.7188
6	0.0592	0	0	0	0	0	0.3399	0	0.6009
7	0	0.1879	0	0	0.1422	0	0.1771	0	0.4929
8	0	0	0	0	0.3122	0.1189	0	0.1576	0.4113
9	0	0	0	0.0601	0	0	0	0.9399	0
10	0	0	0	0	0.1272	0	0	0.4266	0.4462
12	0	0	0	0	0.6051	0	0	0.2271	0.1677
14	0	0	0	0	0	0.3333	0	0	0.6667
15	0	0	0	0	0	0.4444	0	0	0.5556
17	0	0	0	0	0	0	0	0.2939	0.7061
19	0	0	0	0	0.0898	0.0139	0	0.3242	0.5721
20	0	0	0	0	0	0	0	0.0624	0.9376
21	0	0	0	0	0	0	0	0.177	0.823
22	0	0	0	0	0	0	0	0.6074	0.3926
24	0	0	0	0	0	0	0	0.124	0.876
31	0	0	0	0	0.0055	0	0	0.204	0.7905
33	0.3575	0	0	0	0.5841	0	0.0584	0	0
34	0	0	0	0	0.2438	0	0	0.0788	0.6775
35	0.4408	0	0	0	0	0	0.4934	0	0.0658

*DMU: Decision making unit.

Capítulo quinto

Understanding consumers’ perceptions towards Iberian pig production and animal welfare

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Understanding consumers' perceptions towards Iberian pig production and animal welfare

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Abstract: The Spanish market offers a greater variety of Iberian pork products. The aim of this paper is to determine the perception of consumers of several aspects of Iberian pig production and animal welfare depending on the consumers' characteristics. Consumers from two Spanish regions (n=403) answered a questionnaire about their beliefs and the importance of pig production, their purchase intentions and their willingness to pay. Consumers were segmented according to their level of knowledge about Iberian pig production. The results of this work indicate that consumers have poor knowledge about Iberian pig production. Even so, consumers show a remarkable preference for Iberian products, especially when the animals are reared freely and in natural conditions, giving great importance to animal welfare. Consumer preferences indicate the importance of emphasizing Iberian traditional pig product characteristics on the label to promote their purchase choices.

Keywords: local breed, knowledge, beliefs, animal welfare, purchase choice.

1. Introduction

In the past few years, consumers' awareness of the different ways in which food is produced has increased (Pejman et al., 2019). An increasing preference and demand for organic and high welfare animal-based food products have been reported in different studies (Alonso et al., 2020; Kallas et al., 2013; Vietoris et al., 2016). Because of this, consumers are demanding more information on food labels (Pejman et al., 2019). In particular, Spain is one of the EU countries with higher demand for information about food production aspects according to Eurobarometer (European Commission, 2016). At the time of purchase, consumers receive different types of information that can affect their choice among the great variety of products available. This information is used by consumers to infer the quality of the product because although the quality of some foods, like meat, cannot be directly evaluated before purchase, quality expectations, to some extent, are created by the available internal and external cues (Grunert et al., 2004). The information that consumers may consider most important in the choice of a product depends on personal and situational characteristics and on the product itself (Dimara & Skuras, 2005; Liljenstolpe, 2011; Verlegh & Van Ittersum, 2001).

As a general rule, consumers have low knowledge of livestock production systems (Cardoso et al., 2017; Clark et al., 2019). In this sense, differences between consumers from urban and rural areas can be found (McEachern & Seaman, 2005). Rural consumers are more likely to have contact with livestock and have a more positive attitude towards livestock practices (Krystallis et al., 2009) or simply belong to the livestock community, thereby influencing their opinions as consumers (Te Velde et al., 2002). Furthermore, information about the production system is not always available, although some labels (i.e. Protected Designations of Origin (PDO) and organic) are related to specific production systems. In this sense, production systems influence purchasing decisions, with a preference for outdoors (access to outdoor areas for only part of their lives) or extensive (farming husbandry where the pigs can run around outside on pasture/grasslands and roam freely on a large area) livestock systems (Díaz-Caro et al., 2019; Dransfield et al., 2005; Krystallis et al., 2009; Mesías et al., 2005), probably because consumers expect higher quality in this type of product (Scholderer et al., 2004), although this is not always demonstrated (Bonneau & Lebret, 2010).

The breed or genetics can also influence the quality of meat and meat products (Alonso et al., 2015; Plastow et al., 2005) and its sensory acceptability to consumers (Meinert et al., 2008; Straadt et al., 2013). Breed might also influence the purchase of meat products (Lee et al., 2017). Despite that, information about the breed is not always available. However, in some cases meat products from some PDO like, for instance, Dehesa de Extremadura, Los Pedroches (European Commission, 2019) the breed can be known. In addition, meat from some specific breeds is also labelled. In Spain, for example, meat from certain breeds like Iberian and Duroc is related to higher quality and it is possible to find it labelled. Consequently, breeds can be one of the factors that can affect consumers' purchasing decisions. In fact, previous studies (Díaz-Caro et al., 2019; Mesías et al., 2009) indicate that Spanish consumers have a preference for local breed products.

Furthermore, the price of pork products is an important extrinsic factor that can affect consumers' purchasing decisions (Díaz-Caro et al., 2019; Mesías et al., 2009). One of the reasons is that the quality of meat products cannot be evaluated before purchase and, because of that, when consumers are uncertain or they have more difficulties determining the quality of meat, the price can be used to create a quality judgment (Papanagiotou et al., 2013). In fact, in the same study, the price was slightly more important in the perception of quality than in the intention to buy. Some people associate a higher price to higher quality, especially for some type of products (Gil & Sánchez, 1998). Sometimes, a lower price can be associated with lower quality because decreasing the price is a marketing strategy some supermarkets use to sell meat close to the sell-by date (Schnettler et al., 2008).

Although the intensification of animal production in most farms is increasingly common (Clark et al., 2019), traditional production can still be found in some countries, mainly related to autochthonous breeds (Čandek-Potokar et al., 2019). For instance, Spain is the fourth largest pig producing country worldwide, the 2nd largest in Europe (MAPA, 2019).Spain has developed an export-oriented pork industry that is heavily concentrated. The intensive production system is predominant but coexists with a traditional pig farm model system. The major component is the Iberian traditional pig production that differs considerably from the conventional system. This local breed has been traditionally bred in the SW of the Iberian Peninsula (De Miguel et al., 2015), where it is perfectly adapted to the pasture ecosystem (Benito et al., 2006). This local production is managed extensively if natural resources are available, mainly during the finishing period where pigs are exclusively fed acorns and grass (Lopez-Bote, 1998). This breed is characterized by the high-quality of its cured products, with Iberian acorn-fed ham being the largest component (Mesías et al., 2009). Therefore, local Iberian pig production offers an added value in their products that cannot be found in commercial white pig products (Lopez-Bote, 1998).

Iberian pig production has achieved great success in recent times. The economic development of the country and the globalization of the markets has led to an increase in the demand for traditional and high-quality Iberian pig products (Estévez et al., 2003; Lopez-Bote, 1998; Ventanas et al., 2005). However, the scarcity of existing hectares of *dehesa* and an orientation towards more economically profitable intensive production systems by Iberian pig farmers limit the number of pigs that are produced exclusively with natural resources (Mesías et al., 2009). Because of that, the increase in Iberian pig production has resulted in the use of crossbreeds between Iberian and Duroc and in the more intensive production, expanding even outside the traditional regional framework of this breed (Nieto et al., 2019) and reaching 10% of the total number of Spanish pigs (MAPA, 2019). This has generated the possibility of finding different categories of Iberian pork products with different qualities and production systems in the market (Tejerina et al., 2012).

Previous works have studied consumers' preferences for Iberian pork products (Díaz-Caro et al., 2019; Mesías et al., 2009, 2010), showing a preference for traditional Iberian meat products. These works were carried out in the traditional Spanish region of Iberian pig production. Due to the large expansion outside the traditional production area for Iberian pork products and to the fact that consumers' behaviour towards meat and meat products are affected by multiple factors (Font-i-Furnols & Guerrero, 2014), it is of interest to study the preferences of consumers not only in the traditional Iberian pig production region but also outside it.

The aim of this work is to determine the perceptions of consumers towards several aspects of Iberian pig production and animal welfare depending on the consumers' degree of knowledge about Iberian pig production and their demographic characteristics. Particularly, (a) beliefs towards animal welfare and Iberian pig production, (b) the importance of intrinsic and extrinsic cues when purchasing pork, (c) the purchase intentions for pork depending on management aspects, and (d) the willingness to pay (WTP) for Iberian pork from different production systems will be studied. Furthermore, the work aims to determine the relative importance of the breed, production system and price when purchasing products, depending on consumers' characteristics.

2. Material and Methods

2.1. Data collection

Data were obtained through paper questionnaires completed by 403 consumers of pork and pork products in four trials, two in 2016 and two in 2017, in Spain. The recruitment was carried out trying to mimic the Spanish National population distribution (INE, 2016) . In each of the four trials, 100 or 101 consumers were recruited. Two trials were performed in the North-East region (NE), in Barcelona city, located in the most intensive pig production area of Spain (Catalonia). In this place, consumers were selected randomly from a big consumers' database following the national distribution. The other two trials were performed in the South-West region (SW), one in Córdoba and one in Badajoz cities, corresponding with the traditional Iberian pig production area (MAPA, 2019). In these two locations, the studies were carried out at universities. Consumers were selected by personal contacts trying to reproduce the national population. However, younger consumers were overrepresented and older consumers were underrepresented and this could have an effect on the results obtained and need to be considered as it is shown in **Table 1**, where consumers' demographic characteristics by region are presented. In each region, 15 sessions were performed with a minimum of 10 and a maximum of 30 consumers per session. The average time for completing the questionnaire was 30 minutes.

Table 1. Consumers' characteristics by area and knowledge about Iberian production (%)*.

	Region		**Knowledge**	
	NE*	**SW***	**No**	**Yes**
n	201	202	294	109
Region				
NE*			59.52	23.85
SW*			40.48	76.15
Age group				
< 25	8.50	29.35	17.81	22.02
25-40	29.00	25.37	26.37	29.36
40-60	42.50	38.81	41.44	38.53
> 60	20.00	6.47	14.38	10.09
Gender				
Male	47.76	50.99	42.86	66.97
Female	52.24	49.01	57.14	33.03
Educational level				
Basic studies	29.50	17.41	27.05	13.76
University	33.50	61.19	40.41	66.06
Vocational education	37.00	21.39	32.53	20.18
Employment situation				
Student	9.95	34.65	20.41	27.52
Self-employed	6.47	3.47	4.42	6.42
Public employee	5.47	43.07	20.41	34.86
Retired	15.42	3.47	10.54	6.42
Employee	55.22	13.86	39.12	22.02
Unemployed	7.46	1.49	5.10	2.75

*Spanish distribution (INE, 2016): Age group (<25: 9.38%; 25-40: 27.52%; 40-60: 42.38%; >60: 20.72%);Gender (Male: 49.07%; Female: 50.93%); Educational level (Basic studies: 41.65%; University: 35.75%; Vocational education: 22.60%). NE: Northeast, SW: Southwest.

2.2. *Questionnaire design*

The design of the questionnaire was based on the existing literature on consumer preferences and perceptions (Feldmann & Hamm, 2015; Lagerkvist et al., 2006; Stolz, et al., 2011; Wägeli et al., 2016; Zagata, 2012) and the questions were adapted to the context of Iberian pig production. Even though the Iberian pork is less present in supermarkets in the NE region than in the SW region, it is possible to find it. Although this difference, additional information was not previously given to the consumers before answering the questionnaire. This allows us to evaluate the opinion of the consumers in a real situation without the effect of the information on their response (Tomasevic et al., 2020), because it has been proved that information can influence consumer's answer (Tuyttens et al., 2011). The questionnaire was structured in three parts. The first part assessed the consumers' knowledge about Iberian pig production using three questions about the management criteria for Iberian pigs and three more about the categories of Iberian pig products. These questions have a true or false answer and can be used to classify consumers according to their real knowledge on this subject. Secondly, the questionnaire covers 10 items related to beliefs, 8 items about the importance of pork characteristics when purchasing products and 13 items about purchase intentions and WTP (see Appendix 1). These questions were answered on a 5-point scale ranging from 1: 'I strongly disagree' to 5:'I strongly agree'. Finally, the socio-demographic characteristics of consumers (gender, age, education level, and employment situation) were recorded.

2.3. Conjoint analysis

Conjoint analysis was conducted to determine the relative importance of three attributes in the purchase of pork in Spain: breed, production system and price of pork. These attributes were selected because they refer to very relevant aspects in Iberian pig production and pork consumption and it was aimed to see its contribution to the consumers' purchasing decisions. Breed had two levels, white pig and Iberian pig. They were selected based on the interest to determine the importance of the Iberian breed in the purchasing intention in comparison to the most common white pig. The production system had also two levels, extensive and intensive. These two levels were selected because Iberian pig can be produced using these two production systems. Finally, price had also two levels, 7 €/kg and 12 €/kg. The low price is the average price for pork from white pigs while the high price is the average price for pork from Iberian pigs. These attributes were chosen due to the importance of these characteristics in the consumer's purchasing indicated by other authors (Font-i-Furnols et al., 2011; Mesías et al., 2005, 2009). A complete design, considering all the 8 possible combinations were used. Therefore, consumers received 8 labels (one of each combination of the 3 factors) identified with a random code (see example in **Figure 1**). Consumers were asked to order the labels according to their purchasing preferences from 1 (most preferred) to 8 (least preferred).

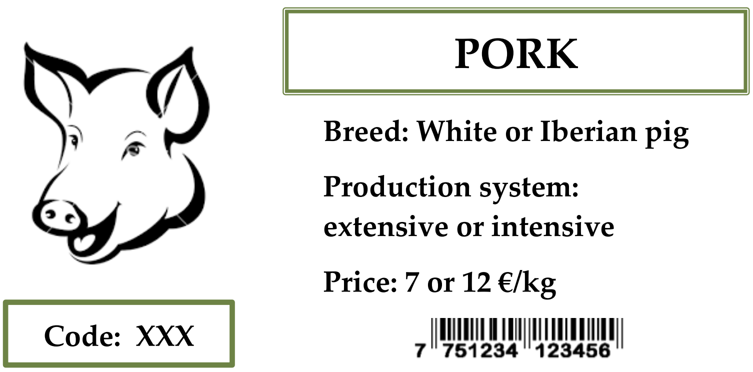

Figure 1. Pork label presented in the conjoint analysis.

2.4. Data analysis

Data analysis was performed with the software SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Initially, a principal component analysis (PCA) was performed with the FACTOR procedure. PCA was performed separately for the questions about beliefs, the importance of pork characteristics and WTP and it allowed finding similarities between questions. Those questions that were close considering the 1st and 2nd principal components and that had a comparable meaning were averaged for the following analyses (**Table 2**). As a result, for the final analysis 6 questions about beliefs, 4 questions about importance and 6 about WTP were considered.

For each of the questions, the Generalized Linear Model (GLM) procedure was applied. The model included as fixed effects region, age group, gender, education level and employment situation. Differences between least-square means were obtained at P<0.05 level by means of Tukey test. A non-parametric Kruskal-Wallis test was performed previously with the NPAR1WAY procedure, but since there were no relevant differences between both statistical analyses, the parametric analysis of variance was considered (O'Mahony, 1986) since it allows us to have more information.

Following, consumers were divided into two groups according to their knowledge about Iberian production and products, which was evaluated in six questions. Three questions about the term "Iberian pig", to determine if it defines this type of pig as a pure breed, raised in free-range and fed acorn. According to Spanish national legislation (Real Decreto 4/2014) the three answers were false. And three questions about how the different types of Iberian products are defined by their management: "*bellota*" as fed by acorn in the fattening period, "*cebo de campo*" as fed by compound feed in free-range and "*cebo*" as fed by compound feed in intensive conditions. According to the Spanish national legislation (Real Decreto 4/2014) all of them are true. Consumers were considered to have knowledge (connoisseurs) about Iberian production if they answered two or three questions about Iberian criteria correctly and two or three questions about Iberian pig management also correctly. Else, they were considered non-connoisseurs about Iberian characteristics. An analysis of variance was performed for beliefs, importance of pork characteristics at purchase and WTP questions considering the classification of consumers by knowledge about Iberian as a fixed effect.

A nonmetric conjoint data was analysed using the TRANSREG procedure of SAS. The model applied considers the monotonic transformation with the sum of all the part-worth utilities for each attribute equal to zero. This is a general and flexible model, usually used in qualitative data. Although the price is numeric, the objective was to include a low and a high price and thus, it has been considered as qualitative in the analysis. The relative importance of each factor was obtained, as well as the utility values associated with each level. The analysis was performed for the entire sample and also for segments of consumers according to the level of knowledge, the region and city.

Table 2. First and second factors (PC1 and PC2) of the Principal Component Analysis (PCA) by group (beliefs, importance and purchasing intentions).

Beliefs	**PCA***	**PC1**	**PC2**
I think that the current requirements for animal protection and welfare should be improved on Spanish farms.		0.36	0.24
I think that Iberian pigs…			
are reared to achieve higher standards of welfare.		0.53	0.34
are reared for better welfare than commercial white pigs.		0.63	-0.30
I think that Iberian pork and meat products…			
are of a high quality.	a	0.68	0.46
are very tasty.	a	0.71	0.38
are healthy.	a	0.64	0.04
have higher quality than those from commercial white pigs.	b	0.75	-0.37
are tastier than those from commercial white pigs.	b	0.73	-0.29
are healthier than those from commercial white pigs.	b	0.62	-0.59
are too expensive.		0.43	0.38
Importance of pork characteristics			
When I buy pork and pig meat products,….			
food labels are important for me.		0.64	0.39
acorn-fed category is important for me.	c	0.72	0.43
the Iberian origin criteria is important for me.	c	0.69	0.39
the PDO certification is important for me.	c	0.66	0.21
it is important for me that pigs are reared free.	d	0.74	-0.48
it is important for me that pigs are reared in natural conditions.	d	0.78	-0.48
the breed is important for me (if they are Iberian pigs).	e	0.62	-0.11
the type of feed is important for me (if they are Iberian pigs).	e	0.78	-0.20
Purchase intentions and willingness to pay			
My purchase choice would be negatively affected if I would know that…			
pigs are reared in intensive conditions.	f	0.64	-0.31
sows are kept in crates.	f	0.65	-0.48
pig tusks are removed.	g	0.63	-0.61
pig tail docking is still practiced.	g	0.68	-0.57
pigs are physically castrated.	g	0.65	-0.52
I would pay more for Iberian pork and pig meat products…			
with an animal welfare certificate.	h	0.65	0.32
with an organic certificate.	h	0.68	0.26
with a GMO-free certificate.	h	0.59	0.30
with a PDO certification.		0.43	0.54
from free-range pigs.	i	0.70	0.40
from pigs reared in natural conditions.	i	0.71	0.43
from pigs transported without injury to the slaughterhouse.	i	0.68	0.28
I would pay more for higher quality food.		0.28	0.18

*Items with the same letter in the PCA column were considered together for the analysis.

3. Results and Discussion

3.1. Consumers' characteristics

The sociodemographic characteristics of the consumers by region are shown in **Table 1**. The proportion of consumers with university studies was higher in the SW region compared to the national statistics, probably because the study was carried out at universities and this was not a selection criteria. This also might explain the higher percentage of public employees included in this region. Another reason for these figures is that the SW region has a higher percentage of public employees compared to the NE region, which has the lowest percentage in Spain (INE, 2019; Spanish Ministry of Finance, 2019). In addition, the unemployment ratio of the respondents was lower than the Spanish average, with unemployed consumers being underrepresented. Since the education level or employment situation did not affect consumers' responses (see the results below), these biases seem to be unimportant and do not have an effect on the conclusions of the study.

Consumers' characteristics based on Iberian pig knowledge (**Table 1**) show that the percentage of people surveyed who know the characteristics of Iberian pig production was very low (27.05%). Clark et al. (2019) also show that, in general, consumers have a low level of knowledge about animal production systems. In particular, knowledge about Iberian pig production was higher in the SW than the NE region (41.1% *vs.* 12.9%, respectively). This is probably due to the fact that Iberian pig production is rooted in the SW of Spain. Most of the consumers that stated that they have knowledge about Iberian pig production were men (67.0%). In addition, the knowledge of Iberian pig production increases with the education level. The age group and employment situation were not remarkable in this aspect since they did not make a difference.

3.2. Beliefs about Iberian production and pork products

No significant differences were found in beliefs by the level of education and employment situation while region, age and gender significantly affected some of the beliefs (**Table 3**).

The majority of consumers that responded to this survey answered that the animal welfare and protection requirements for Spanish farms should increase (average score of 4.1). This finding is in line with the answers obtained from Spanish citizens in the last Eurobarometer (2016). In particular, this demand was significantly emphasized ($P<0.05$) by women and NE consumers. Several works have shown that women are more concerned about animal welfare than men (Kendall et al., 2006; Pejman et al., 2019; Vanhonacker et al., 2007). Some previous works show that the importance of animal welfare decreases with age (Clark et al., 2017; Cornish et al., 2016), but this was not observed in the present work.

Table 3. Consumers' beliefs, importance of pork characteristics when purchasing and willingness to pay by consumers' demographic characteristics.

	Mean	**Region**		**Age group**				**Gender**			**P-value**		
	global	**NE***	**SW***	**< 25**	**25-40**	**40-60**	**> 60**	**M***	**F***	**RMSE***	**Region**	**Age**	**Gender**
Beliefs													
I think that the current requirements for animal protection and welfare on Spanish farms should be increased.	4.14	4.3	4.0	4.2	4.3	4.1	4.1	4.0	4.3	1.01	**0.008**	0.683	**0.005**
I think that Iberian pigs are reared…													
in high welfare standards.	3.67	3.5	3.7	3.1^{b}	3.4^{b}	3.7^{a}	4.1^{a}	3.6	3.6	0.90	0.306	**<0.001**	0.978
in a better welfare than commercial pigs.	3.78	3.8	3.7	3.4	3.6	3.8	4.1	3.8	3.7	1.05	0.539	0.119	0.760
I think that Iberian pork and meat products…													
are of a high quality, very tasty and healthy.	4.14	4.1	4.2	3.9^{b}	3.9^{b}	4.1^{b}	4.5^{a}	4.1	4.1	0.70	0.191	**0.002**	0.757
have higher quality, tastier and healthier than pork and meat products from commercial pigs.	4.02	4.0	4.0	3.8	3.9	4.1	4.2	4.0	4.0	0.85	0.981	0.233	0.852
are too expensive.	3.81	3.9	3.8	3.8	3.8	3.8	4.0	3.7	4.0	0.95	0.232	0.652	**0.010**
Importance of pork characteristics													
When I buy pork and pig meat products, it is important for me…													
the food labels.	4.06	3.9	4.3	3.5^{b}	4.1^{ab}	4.2^{a}	4.5^{a}	4.1	4.1	0.98	**0.003**	**0.013**	0.878
the Iberian breed, fed-acorn and PDO criteria.	3.96	3.9	4.1	3.7^{b}	3.9^{b}	4.1^{ab}	4.4^{a}	4.0	4.0	0.77	0.159	**0.007**	0.303
that the pigs have been reared in natural conditions and free.	4.06	4.2	4.2	4.3	4.0	4.2	4.3	4.1	4.3	0.92	0.988	0.359	0.204
the breed and the type of feed if it is from Iberian products.	3.96	4.0	4.2	3.7^{b}	3.8^{b}	4.2^{ab}	4.5^{a}	4.1	4.0	0.87	*0.087*	**0.001**	*0.088*
Purchase intentions and willingness to pay													
My purchase choice would be negatively affected if I would know that…													
pigs are reared in intensive conditions and sows are kept in crates.	3.67	3.7	3.7	3.9	3.8	3.6	3.4	3.6	3.7	1.10	0.790	0.395	0.251
pigs are physically castrated, their tusks are removed or tail docking is practiced.	3.01	3.2	2.9	3.2	3.2	3.0	2.8	2.8	3.3	1.24	*0.070*	0.515	**<0.001**
I would pay more for Iberian pork and pig meat products…													
with an animal welfare, an organic or a GMO free certificates.	3.85	4.0	3.9	4.1	4.0	4.0	3.8	3.9	4.0	0.90	*0.452*	0.754	*0.078*
with a PDO certification.	4.04	4.0	4.3	4.2	4.0	4.2	4.2	4.2	4.1	0.95	*0.078*	0.529	0.468
from pigs reared in natural conditions, in free-range or transported without injury to the slaughterhouse.	4.17	4.2	4.3	4.2	4.2	4.3	4.4	4.2	4.4	0.78	0.390	0.818	**0.011**
I would pay more for higher quality food.	3.81	3.8	3.9	3.9	3.9	3.8	3.7	3.7	3.9	1.01	0.385	0.703	**0.028**

* NE: northeast; SW: southwest; M: male; F: female; RMSE: root mean square error. P-values for educational level and employment situation were >0.05 for all the items.

The opinions on the degree of animal welfare for Iberian pigs were generally positive. It supported a better view of the Iberian pig than the commercial white pig. In fact, the score of the consumers regarding the statement "Iberian pigs are reared in better welfare standards than commercial pigs" is 3.78, which is in between 'neither agree nor disagree' and 'agree'. Consumer preferences are influenced by marketing aspects (Font-i-Furnols & Guerrero, 2014) and citizens relate Iberian pigs with an extensive system that is environmentally friendly and fed natural resources, although the highest percentage of Iberian pigs are currently reared in the intensive system (RIBER, 2019). Therefore, consumers had better opinions of the animal welfare of Iberian pigs, probably because of their beliefs and attitudes toward production systems (Busch et al., 2019). In this case, citizens associate Iberian pigs with an extensive system and commercial white pigs with an intensive system and some works show that consumers consider that outdoor systems provide higher welfare standards (Sinclair et al., 2019; Sørensen & Schrader, 2019). The opinions about the status of the welfare of Iberian pigs depend on the age of the consumers. In this sense, participants under the age of 40 considered the level of animal welfare for Iberian pigs to be lower than those respondents over 40. This can be affected by the fact that, in general, animal welfare is more important for young consumers than older ones (Clark et al., 2016; Cornish et al., 2016).

Consumers consider that Iberian pork and pork products are high quality, tasty and healthy and that these qualities are higher in Iberian pork than in pork from commercial white pigs (average scores of 4.1 and 4.0, respectively). In fact, other works have shown that Spanish consumers perceive Iberian pork and pork products to have excellent sensorial and nutritional qualities (Mesías et al., 2013). In addition, consumers over 60 years old considered Iberian products to be superior ($P<0.05$) in terms of their quality, taste and health compared to younger consumers. However, no significant differences were found with respect to the age, gender, area and the educational level of the participants about the statement that meat from Iberian pigs is of better quality than that of commercial white pigs.

Generally, Iberian pork and pork products are more expensive than those from white pigs. Regarding the belief that Iberian pork and pork products are too expensive, scores were close to 'agree'. This score was significantly higher in women than men (4.0 *vs.* 3.7), which is probably related to the fact that women are still primarily responsible for food shopping.

The effect of the degree of consumer knowledge about Iberian pig production on the beliefs toward animal welfare and Iberian production and quality aspects are presented in **Table 4**. Non-connoisseur consumers of Iberian pig production aspects scored the statement that current animal protection and welfare requirements for Spanish farms should be increased greater ($P<0.05$) compared to connoisseurs (**Table 4**). These results are in line with the consumer concerns about animal welfare, which is related to the level of information or knowledge (Pejman et al., 2019). Although consumers do not have information on livestock production systems, they have a negative opinion of intensive production systems (Clark et al., 2019). No significant differences ($P>0.05$) between the levels of knowledge of consumers were found regarding whether Iberian pigs have better animal welfare than commercial breeds. As previously mentioned, the non-connoisseurs associate Iberian pigs with extensive systems while the connoisseurs know the different Iberian pig production systems (extensive and intensive systems). Independently of the level of knowledge of the consumer, all of them believe that Iberian pork products are high quality, very tasty and healthy and that these characteristics are higher with Iberian pigs than commercial white pigs. This result confirms the fact that Iberian pork and products are well known as high-quality products (Lopez-Bote, 1998).

Table 4. Consumers' beliefs, importance of pork characteristics when purchasing and willingness to pay by knowledge of consumers about Iberian production.

	Knowledge			
	No	**Yes**	**RMSE***	**P-value**
Beliefs				
I think that the current requirements for animal protection and welfare on Spanish farms should be increased.	4.3	3.7	1.01	**<0.001**
I think that Iberian pigs are reared…				
in high welfare standards.	3.7	3.5	0.93	**0.012**
in a better welfare than commercial pigs.	3.8	3.6	1.07	*0.083*
I think that Iberian pork and meat products…				
are of a high quality, very tasty and healthy.	4.2	4.0	0.71	**0.037**
have higher quality, tastier and healthier than pork and meat products from commercial pigs.	4.1	3.9	0.85	0.156
are too expensive.	3.9	3.5	0.95	**<0.001**
Importance of pork characteristics				
When I buy pork and pig meat products, it is important for me…				
the food labels.	4.0	4.2	0.99	0.176
the Iberian, acorn and PDO criteria.	4.0	3.9	0.79	0.619
that the pigs have been reared in natural conditions and freely.	4.1	3.9	0.94	0.149
the breed and the type of feed if it is from Iberian products.	3.9	4.1	0.89	**0.027**
Purchase intentions and willingness to pay				
My purchase choice would be negatively affected if I would know that…				
pigs are reared in intensive conditions and sows are kept in crates.	3.7	3.5	1.10	0.157
pigs are physically castrated, their tusks are removed or their tail docking is performed.	3.2	2.6	1.27	**<0.001**
I would pay more for Iberian pork and pig meat products…				
with an animal welfare, an organic or a GMO-free certificates.	3.9	3.8	0.91	0.238
with a PDO certification.	4.0	4.1	0.95	0.222
from pigs reared in natural conditions, in free-range or transported without injury to the slaughterhouse.	4.2	4.1	0.79	0.154
I would pay more for higher quality food.	3.8	3.9	1.02	0.245

*RMSE: root mean square error.

Iberian pig connoisseurs did not believe that Iberian products were too expensive like non-connoisseurs. It can be hypothesized that the knowledge of the production systems makes the consumers more conscious of the work needed to produce the animals and the products and this probably influences their perception of the price of the product. In fact, Liljenstolpe (2011) found that price sensitivity is related to the concerns of consumers regarding some aspects such as food safety issues, animal welfare issues, or intermediate issues.

3.3. Importance of pig production and commercialization aspects

Regarding the importance of pig production and the commercialization aspects of pork and pork products (**Table 3**), it is possible to see that food labelling and the fact that pigs are reared free and in natural conditions received the highest scores on average (4.06 each). Janssen et al. (2016) in a meta-analysis study reported that to meet consumer preferences it would be advisable to label about the husbandry system, allowing a differentiation for animal-welfare systems. The statements relative to Iberian pigs regarding the Iberian, acorn-fed, PDO, breed and type of feed criteria followed them with an average score of 3.96 each. Thus, all these aspects of pork production and commercialization are therefore important for consumers.

Age significantly affected most of the consumers' importance placed on the aspects of pig production when buying pork (**Table 3**). The importance of food labelling increased when age increased. The criteria related to Iberian pig production and products such as breed, type of feed (where acorn was highlighted), or PDO also increased in importance as age increased. This is probably due to the fact that older consumers considered Iberian products to be superior in terms of quality, taste and health compared to younger ages.

The living region only significantly influenced ($P<0.05$) the importance of labelling. SW consumers had a greater score for the importance of labelling when buying pork and pig meat products than NE consumers (4.3 *vs.* 3.9). The information on a label is an important factor that affects consumers' purchasing decisions (Bandara et al., 2016; Cornish et al., 2020; Sørensen & Schrader, 2019), being more remarkable in Iberian products due to the great variety offered. The higher importance of the labelling among SW consumers could be explained by the fact that in this region, it is easier to find Iberian products and the level of knowledge about Iberian products is higher. Consequently, food labels are important to identify the characteristics of pork products, mainly Iberian products. In general, consumers are proud of products from their own region and origin is an important parameter of buying preferences (Díaz-Caro et al., 2019; Likoudis et al., 2016; Papanagiotou et al., 2013; Wägeli et al., 2016). The importance of different criteria associated with the labelling of pork and pig meat products (Iberian breed or production system) was not significantly different between regions. However, SW consumers showed a tendency ($P=0.09$) to place greater importance on breed and feeding in Iberian products, probably because of the high knowledge in this region about these products and their characteristics in terms of breed and feeding. This may be because Iberian traditional pig production is based on a pure breed and extensive systems in the *dehesa*. These production characteristics are embedded in SW cultural heritage (Ríos-Núñez & Coq-Huelva, 2015). Therefore, consumers from this region prefer products with these

Iberian pig characteristics so that they support local farmers (Papanagiotou et al., 2013). In fact, this is the only significant factor of importance when buying pork that is significantly different between Iberian pig knowledge groups (**Table 4**). Consumers with good knowledge of Iberian pig production considered the breed and type of feed more than important than non-connoisseurs (4.1 *vs*. 3.9).

3.4. Purchase intentions and willingness to pay

Consumers agree (average score of 3.7) that their choice to purchase pork would be negatively affected if pigs are reared in intensive conditions and sows are in crates (**Table 3**). Similarly, German consumers considered positive purchase pork that comes from sows that had no movement restrictions (Grunert et al., 2018). Also, Carlsson et al. (2005) reported a higher willingness to pay for meat from animals with outdoor access. Nevertheless, in the present work, consumers neither agree nor disagree (average score of 3.0) regarding castration, tusk removal, or tail docking. In fact, even though the surgical castration of piglets is criticized because of animal welfare issues (Prunier et al., 2006), a low importance placed on castration in consumers' purchasing intention or worries have been found in other works carried out in western (Kallas et al., 2013) and Eastern (Tomasevic et al., 2020) Europe, in accordance with the present results. In fact, in the study of Kallas et al. (2013), European consumers (from The United Kingdom, The Netherlands, Germany, Italy, France and Spain) consider surgical castration less important than other productive aspects (housing conditions) in relation to animal welfare. In opposition to this work, Liljenstolpe (2011) found that Swedish consumers who were classified as being concerned about animal welfare considered no castration to be an important point that positively affects their willingness to pay, in opposition with consumers being more concerned about food safety or being concerned with both. In the same direction, a study focused on castration and its alternative showed that German organic consumers' willingness to pay for meat from castrated pigs without anaesthesia was lower than for other alternatives. In addition, for most of the consumers, the highest discussed the criterion that affects negatively the choice of castration without anaesthesia was animal welfare. This changed substantially when the pain relief is applied to the castration (Heid & Hamm, 2013). Consumers also placed greater importance on other animal welfare aspects such as naturalness or extensive systems, as reported in the study of Sørensen and Schrader (2019). Regarding WTP, the highest scores were obtained by Iberian meat from free-range animals reared in natural conditions or transported without injury to the slaughterhouse (4.2) and by Iberian meat with PDO certification (4.0). Although consumers agree that they would pay more for organic and GMO-free meat, for Iberian meat from certified farms with higher animal welfare standards and for higher quality food, the scores were slightly lower (3.9 and 3.8, respectively). Certification is an important factor that affects consumer WTP, as demonstrated in Mesías et al. (2005) and Likoudis et al. (2016).

Most of the significant differences in purchase intentions and WTP were related to the gender of the consumer (**Table 3**). As previously reported, women were more sensitive to issues related to animal welfare (Clark et al., 2017; Font-i-Furnols et al., 2019; Pejman et al., 2019). Their purchase choice would be most negatively affected if the pork and pig meat products came from pigs that were physically castrated or their tails and tusks were cut. Nevertheless, as commented above, this aspect seems to be not as important compared with other factors. In addition, women would pay more for Iberian meat products from free-range animals that were reared in natural conditions or transported without injury to the slaughterhouse than men, indicating again the highest importance placed on animal welfare issues, which is also expressed by women paying more for higher quality food than men. Beardsworth et al. (2002) also found that women more frequently choose foods produced with higher animal welfare than men.

Though some works found that the region may influence purchase intentions and WTP (Clark et al., 2017), no differences were found for WTP related to the region of the consumers in the present study. Only a tendency ($P<0.10$) can be seen that NE consumers' purchase choices were more negatively influenced by physical management (physical castration, tusks removal, or tails cut) than SW consumers. The primary sector is more important in the SW region than in the NW region (INE, 2019) because it is a rural area. Therefore, SW consumers have more contact with Iberian farmers than NE consumers (urban area), thus generating more positive attitudes towards them (Krystallis et al., 2009). In the same line, SW consumers showed a greater WTP for PDO certified products ($P=0.08$). The Iberian pig PDO (Dehesa de Extremadura, Los Pedroches, Jabugo and Guijuelo) is found in SW Spain (MAPA, 2019). Consequently, PDO certified Iberian pig products are local products in the SW region. Therefore, SW consumers showed a higher WTP for these local products (Likoudis et al., 2016), considering their local origin and added value (Wägeli & Hamm, 2015). In other studies, SW consumers' preference for local products has been observed for Iberian products (Díaz-Caro et al., 2019; Mesías et al., 2013).

No differences were found related to the effect of consumer age on purchasing intentions and WTP. However, in other works, it was observed that purchase choices were more negatively influenced by physical management (tusks removal or tails docking) or intensive systems for young consumers (Cornish et al., 2020). In addition, young consumers would pay more for Iberian meat products with animal welfare or organic certification (Font-i- Furnols et al., 2019).

Finally, the choice to purchase pig meat products from physically castrated animals and animals subject to other management practices (tusk removal and tails docking) would be more negatively affected for the non-connoisseurs of Iberian products than for consumers with knowledge about their production (**Table 4**). The perception of animal welfare may be influenced by the level of knowledge (Pejman et al., 2019). A lack of knowledge about a management practice can produce a more negative reaction of consumers towards this practice. Thus, non-connoisseurs of practices like castration, tusk removal or tail docking can view them as negative because they do not know that these practices are usually performed and there is a reason to do them. The meat of entire male pigs may have a disagreeable odour and flavour known as boar taint mainly due to two compounds (androsterone and skatole) that are accumulated in the fat (Font-i-Furnols et al., 2008; Yunes et al., 2019). In traditional breeds (e.g. Iberian pigs), pigs are slaughtered heavier and older. Consequently, if they were left whole, the meat would have greater boar taint risk (Bonneau et al., 2018) because the pig would have reached maturity and, consequently, have lower sensory quality and consumer acceptability (Font-i-Furnols et al., 2008). In fact, boar taint, facilitating the management of pigs and avoiding unwanted pregnancies in extensive animals are the main reasons for castrating Iberian pigs. Even though general consumers do not know about boar taint and how to avoid it (Kallas et al., 2013), it is possible that connoisseurs know that this is a normal practice in Iberian pigs and, because of that, they do not have a negative opinion about castration because they consider physical castration to be necessary.

3.5. Conjoint analysis

The relative importance and utility values of the three factors studied (breed, production system and price) are shown in **Table 5**. Overall, consumers considered pig breed the most important attribute (42.61%) with a marked preference for Iberian pigs. The preference for Iberian pigs is in accordance with other studies (Díaz-Caro et al., 2019; Mesías et al., 2009) where this breed obtained the highest importance among other factors. These results are in line with the results obtained in the surveys carried out in this study where consumers have a better opinion about different aspects (level of animal welfare, product quality, etc.) of Iberian pigs compared to white pigs that influence purchase choices. The second most important attribute was the production system (39.34%). In this case, consumers showed a preference for extensive systems over intensive systems. We emphasize that similar values were obtained for the breed and production system attributes. The likely image of consumers regarding Iberian pigs is an extensive production (*dehesa*) because this has been used commercially for marketing purposes. Nevertheless, only 35% (RIBER, 2019) of Iberian pigs are extensively fattened (including *cebo de campo* and *montanera*) and only 17% of them are in *montanera* (extensive and acorn feeding in *dehesa*). Consumers probably have a lack of knowledge of the reality of the Iberian productive system and this would indicate that the consumers of Iberian meat products have a distorted image of reality. A meta-analysis (Janssen et al., 2016) showed the preference for outdoor production systems because it influences animal welfare, together with other aspects such as stocking density and floor type. Also, Clark et al., (2019) reported that intensive pig production systems have a high perceived risk of increase in animal stress. The preference for extensive systems has been observed in studies on pig production (Díaz-Caro et al., 2019; Dransfield et al., 2005) and also on other livestock species (Font-i-Furnols et al., 2011; Realini et al., 2013). This preference for extensive systems is in accordance with the previous questions, where the intention to pay more for products produced in natural conditions or pay less for products produced in intensive systems was observed. The price of meat was the least important attribute for consumers (18.05%) with the lowest price more preferred than the highest price, which is in agreement with other works (Font-i-Furnols et al., 2011; Mesías et al., 2009, 2013; Realini et al., 2013). However, some works show clusters of consumers that prefer an intermediate or high price compared to the lowest one (Font-i-Furnols et al., 2011; Sasaki & Mitsumoto, 2004). Although consumers consider Iberian products to be too expensive in the results obtained in this study, it can be seen that the breed is the most important factor when choosing a pork product and its production system is the second most important factor.

Table 5. Relative importance and utility values of each attribute for consumers and for each. group.

		Knowledge		Region	
	Global	No	Yes	NE*	SW*
n	403	294	109	201	201
Intercept	4.5	4.5	4.5	4.5	4.5
Breed					
White pig	-1.18	-1.16	-1.25	-1.10	-1.27
Iberian pig	1.18	1.16	1.25	1.10	1.27
Relative importance (%)	42.61	44.12	38.89	44.86	40.93
Production System					
Extensive	1.09	1.06	1.19	0.94	1.24
Intensive	-1.09	-1.06	-1.19	-0.94	-1.24
Relative importance (%)	39.34	40.47	37.08	38.49	39.91
Price					
7€/kg	0.50	0.40	0.77	0.41	0.60
12€/kg	-0.50	-0.40	-0.77	-0.41	-0.60
Relative importance (%)	18.05	15.41	24.03	16.65	19.17
RMSE*	1.55	1.62	1.29	1.73	1.32
R^{2*}	0.54	0.50	0.68	0.43	0.67

*RMSE: root mean square error; R^2: coefficient of determination. NE: northeast; SW: southwest.

When consumers were segmented by their knowledge of Iberian pig production, both groups showed preferences for Iberian pig meat reared in an extensive system with a low price (**Table 5**). In particular, connoisseurs gave more importance to price than non-connoisseurs (24% *vs.* 15%), less importance to the breed (39% *vs.* 44%) and slightly less importance to the production system (37% *vs.* 40%). This is probably due to the fact that the number of connoisseurs is higher in the SW region and in this region the income is lower than in the NE region. Nevertheless, when the WTP for extensively produced meat or high-quality meat was evaluated, no significant differences were found between connoisseurs and non-connoisseurs. Furthermore, this group of connoisseurs is characterized by having more consumers from the SW region. In this region of Spain, the living costs and the incomes are lower than in the NE region (INE, 2019) and this might influence the importance of the price for these consumers. However, a study from Lara (2012) show that amount of Iberian products consumed per capita is higher in SW than the NE region, probably because prices are lower. Also, men are the majority of the connoisseur group, indicating that they probably are more interested in low prices, in accordance with the results obtained before where men would be willing to pay significantly less than women for free-range and higher quality meat. Men also were those that considered the price to be the most important factor in a study carried out in the United Kingdom and Spain on lamb (Font-i-Furnols et al., 2011).

When the analysis was carried out according to region, no important differences between regions were obtained (**Table 5**). In both of them, the relative importance of the breed was the highest (> 40%), followed by production systems (> 38%) and finally, the price (< 20%). In all the cases, Iberian pigs from an extensive production system with a lower price are preferred.

3.6. Limitations of the study

This study has some limitations that might have an influence on the results that have been commented through the text and are summarized in this section.

The first one is a bias in the sample of consumers that participated in the trial, especially in the SW region. In this region, the final sample had an over-representation of young consumers and an under-representation of old consumers. This might have influenced the responses since age has been significant in some of the questions. There are also other biases in the population, as the high number of consumers with high educational level, the high number of public employees and the low percentage of unemployed consumers. These biases are probably due to the fact that the study was carried out at universities.

Another shortcoming is related to aspects of the questionnaire. In this sense, the questions were provided with the same order to all the consumers and grouped by type of question. This was performed in that way because it allowed to simplify the reading of the questions by the consumers and, consequently, reduce the fatigue in answering the questions. This aspect was important because this work was part of a wider study and consumers participated in other activities.

4. Conclusions

In the conditions of the present study, it can be concluded that around 75% of the consumers who participated in this trial did not know which criteria need to be fulfilled by Iberian pig production and which are the characteristics of the different Iberian products. The consumers in this study, even if they were aware or not of the implications of "Iberian pork" and independently on the geographic area studied, consider Iberian products of higher quality, tastier, healthier and produced with higher standards of animal welfare than pork products from white commercial breeds. Consumers also think that Iberian products are too expensive, but this was clearly affected by the degree of knowledge about Iberian production and characteristics, showing the necessity to increase the knowledge to give higher value to the product and understand the price. The labelling and the rearing conditions were considered the most important pork characteristics followed by the breed and rearing conditions. Because of that, the labelling of the products from Iberian pigs that are traditionally produced is of great importance in order to reach a high number of consumers. Probably, it would be advisable that differences in the production systems of Iberian pigs should be clearly provided on the labels than what is currently provided, to avoid misconceptions. Most of the consumers imagined that Iberian pigs are reared extensively in the *dehesa* ecosystem, although two-thirds of Iberian pigs are intensively reared. Information about the husbandry practices, including rearing conditions and feeding system, would allow consumers to take a more informed choice.

The low knowledge about the different types of Iberian pig production among the population supports the opportunity to educate and change some negative beliefs of consumers regarding some production practices and to support pig consumption.

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Capítulo sexto

Exploring sustainable food choices factors and purchasing behaviour in the Sustainable Development Goals era in Spain

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Sustainability 2021, under review

Exploring sustainable food choices factors and purchasing behaviour in the Sustainable Development Goals era in Spain

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Abstract: The aim of the present study was to investigate 1) the ampleness of the concept of food sustainability and its link with sustainable consumption by identifying meaningful typologies and 2) the association of consumer typologies with different farm attributes related to sustainable meat choices. Consumers from two Spanish regions (n=403) answered a paper questionnaire to know their degree of knowledge of sustainability, beliefs, and behaviour, attitudes and preferences towards food sustainability, the importance given to product characteristics and shopping practices. A principal component analysis was conducted to identify groups with similar answers to average some of the questions before the final analysis of variance, which includes demographic classes as fixed effects. A cluster analysis using the most representative questions identified two clusters. Cluster 1 (68.4%) responded to more sustainability-related attributes, and Cluster 2 (31.5%) presented a less expanded concept of sustainability. The origin of the product (local, organic) was important for food purchase practices. The place of residence and gender differences of consumers were the most influential factors. In the conjoint study regarding the purchase of Iberian pork, Cluster 1 remained unwilling to sacrifice outdoor systems and local breed at the expense of the price in the case of the Iberian pig production. The most important demographic differentiator was the region of residence of the consumer. In conclusion, consumers are not aware of the wider aspects included in the sustainability concept. Moreover, the concept of sustainability elicits different meanings to the segments of consumers identified.

Keywords: sustainability concept, consumer behaviour, consumption patterns, sustainable consumption, animal production.

1. Introduction

The global food system is one of the main drivers of climate change and its importance is progressively increasing with the world population growth (United Nations, 2017). Given that one of the most effective strategies to act on climate change is through modifying dietary habits, there is an urgent need to incorporate changes towards a more sustainable diet (Batlle-Bayer et al., 2019). An example of the relevance that sustainable choices have acquired is its insertion at strategic plans and priority goals in The United Nations-led-initiative 'Transforming our world: the 2030 Agenda for

Sustainable Development' that sets out 17 Sustainable Development Goals (SDGs). Likewise, SDG Goal 12 (SDG 12) includes a focus on promoting sustainable consumption and production patterns that guarantee economic growth (United Nations, 2018).

Meeting the grand challenges of our time requires societal transformation that starts from changes in production and consumption patterns (Caron et al., 2018) both linked to the sustainability concept.. The agri-food sector, mainly animal production systems in its pursuit of sustainability, has to integrate several elements such as environmental protection, food safety, animal welfare, and benefits to local producers that concern the consumer (Caron et al., 2018). The change of mentality required with respect to the food system makes necessary to include all the actors involved in the system, especially the consumer (EEA, 2017).

Differences in consumption habits can be significant even within the same country. Noticeable differences exist not only at a national level but also at a more regional/local level in terms of food preferences, habits, food-related behaviour, and attitudes in Europe (Askegaard & Madsen, 1998). Spain is a country with a great diversity of gastronomy with traditional food habits, cultures and lifestyles. According to Jordana (2000) southern European countries have a more traditional food character. The Mediterranean diet and the Atlantic Diet are examples of traditional diets in Spain perceived by Spanish consumers as diverse enough (Askegaard & Madsen, 1998). Some studies have pointed out a shift from the above-mentioned dietary patterns with traditional food products to the consumption of ultra-processed food (higher fat, sugar and salt content) (Esteve-Llorens et al., 2021). Meanwhile other studies did not perceive an increase in variety of food innovation in the Spanish consumer (Guerrero et al., 2009).

A shift toward sustainable farming connected to strong local and regional food systems has been made more apparent after COVID-19 episode (Gracia et al., 2020; OECD, 2020). Urban consumers might be more prone to reconnect with rural roots (Montanari, 1994), while according to Weatherell et al. (2003) in UK, rural-based consumers tend to give a higher priority to "civic" issues in food choice, exhibiting higher levels of concern over food provisioning issues, and showing greater interest in local foods. It remains to be determined to what extent these insights seen in other contexts apply to Spain.

The agri-food system in Spain, and meat production in particular, is immersed in a process of continuous change motivated both by structural factors of the production systems which are closely associated with its internal socio-political forces, and by changes in consumers' consumption patterns (Ríos-Núñez et al., 2015). Spain has developed an export-oriented pork industry that is heavily concentrated (especially in NE Spain) and extremely reliant on world markets. Yet, traditional pig farming in Spain still occurs (being the most important in quantity in the southwestern part of the country) despite the loss of pig farms that have been most acute in some regions (MAPA, 2019) bringing severe damage to local rural economies and loss of its widely diverse agro-ecological terms regions with different agrarian vocations (Ríos-Núñez et al., 2015). Although negative images towards intensive production systems have been recorded in Europe (Clark et al., 2019; Krystallis et al., 2009). Previous studies have found that what people think in their role as citizens related to today's pig production did not appear to significantly influence their pork consumption choices (Krystallis et al., 2009).

All these mentioned differences in food-related aspects are expressed by consumers both in terms of food choice and consumption patterns. Different sustainability-related functions of types are seen to be fundamental lifestyle components and could be fulfilled by a variety of sustainable actions (Onel et al., 2018). Related to animal welfare perception of pork production by consumers, Spanish consumers prefer the conventional farm system with animal welfare improvement and feeding supplementation with natural herbs in comparison to the conventional farming system and food. Yet there is a lack of empirical information regarding consumer perceptions of sustainable consumption in Spain, which limits the extent to which strategies for communication can be effectively theorised and developed.

Having a better understanding of what makes food choices to be more sustainable, could help consumers to make more informed decisions. Consumers thus play a major role in the shift towards more sustainable foods and diets. This study addresses these gaps in the understanding of the concept of sustainable food by consumers. However, food consumption patterns in Spain and consumption practices are missing. Likewise, in the face of the increasing industrialization of the livestock sector, it is interesting to explore the various dimensions of sustainability connected with responsible consumption to advance research in the SDG era. Therefore, the objective of this study is twofold (i) to identify meaningful typologies from the concept of food sustainability and food choices factors framed by SDG 12, and ii) to know how different farm systems attributes affecting purchase behavior are associated with such typologies.

2. Materials and Methods

The present study has applied an integrative and interdisciplinary approach to gain knowledge of the openness of the concept of sustainability by Spanish consumers. Consumers' beliefs, behaviour, importance of product characteristics and preference towards more sustainable behaviours have been analysed, as the consumer is the main actor in the food system. As a means of achieving the two objectives of the study, data was collected in two steps involving a paper questionnaire and a consumer ranking-based test (conjoint analysis). A hall test was performed inviting consumers to a set location, date and time to participate in the trial. The study was carried out between January 2016 and November 2017.

2.1. Consumers

Four hundred and three regular food consumers participated in this study. The design aimed to preselect a balanced gender and age consumer sample according to the Demographics of Spain (INE, 2016). The consumption of meat was a pre-requisite to be included in the sample. Half of the sample (n=202) came from a region with traditional extensive Iberian pig and ruminant farming activity with middle size cities (Badajoz and Córdoba, SW Spain). The other half of the respondents (n=201) lived in the most industrialized pig production region where the second biggest city in Spain is located (Barcelona, NE Spain). For trials performed in NE Spain, consumers were selected randomly from a big consumers' database from a company specialized in consumer studies following the national distribution by gender and age. In SW region, consumers were selected by personal contacts trying to reproduce the national population. Age groups, gender, education level, and employment situation of the respondents were the sociodemographic characteristics analysed.

2.2. Roadmap of the session

Each survey round constitutes a session. A total of 15 sessions per region were performed with a minimum of 10 and a maximum of 30 consumers per session. The session comprised a questionnaire and a consumer ranking-based test (conjoint analysis). No additional information was previously given to the consumers before answering the questionnaire. The average time for completing the questionnaire and conjoint analysis per participant was 30 minutes.

2.3. Questionnaire

The questionnaire was structured in four main blocks (for more details see **Table S1** in supplementary material). The first block of six closed questions (Yes/No/Do not know) corresponded to consumers' level of knowledge about sustainability and its meaning related to food. The second block addressed consumers' beliefs (11 questions) related to food sustainability, product information, food traits related to human health and food origin and brand. It also included behavioural characteristics (18 questions) considering aspects related to purchasing, consumption, and the production of food. Finally, this block evaluated the importance of several aspects regarding food products characteristics and quality (14 questions). Questions from the second block used a 5-point Likert scale ranging from 1 = completely disagree to 5 = fully agree. The third block corresponded to closed-form questions related to socio-demographic characteristics of the consumers (gender, age, education level, and employment situation) and six questions related to shopping practices (for more details see **Table S2** in supplementary material).

The questionnaire was designed according to the research questions of this study and organized following the outline of previous studies (Hemmerling et al., 2015; Laureati et al., 2013; Santurtún et al., 2012). To obtain the final questionnaire, personnel from different Departments at the different Research Centres helped to perform a pilot testing. It improved the ease with which the responders were able to complete the questionnaire (readability and comprehensiveness) which in total reduced the necessary time to fill the questionnaire.

2.4. Conjoint analysis

A conjoint analysis was used to determine the relative importance of various farm systems attributes in the context of purchasing pig meat in Spain due to the current development of the pork industry.

The three farm systems attributes evaluated in this study were 1) breed with two levels (Iberian and white pig), 2) production system with two levels (extensive and intensive), and 3) meat price at two levels (7 € and 12 €). Consumers received eight labels (one of each is a combination of the three factors) that were identified with a random code. Consumers were asked to rank the labels according to their purchasing preferences from the most preferred (1) to the least preferred (8). The two levels of the production system were selected because Iberian pigs can be produced in both production systems (Real Decreto 4/2014). The low price was the average price for pork from white pigs while the high price was the average price for pork from Iberian pigs. Farm attributes evaluated in this study were chosen because of their importance on Iberian pig production and pork consumption as reported in other studies (García-Gudiño et al., 2021; Mesías et al., 2009).

2.5. Data analysis

All the analyses were performed with SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA).

Frequency calculations were performed using the FREQ procedure. Significant differences between clusters, obtained as detailed below, were determined by means of the chi-square test two by two.

Factor procedure of SAS was used to carry out a Principal Component Analysis (PCA) for three sets of questions: beliefs, importance, and behaviour. Questions that were placed close to the first two-dimensional subspaces of the principal component analysis were averaged. **Table 1** shows the correlation of each variable with the first two principal components, the variance accounted for each principal component and the variables that have been averaged in the following analyses. Finally, eight items about beliefs, 14 items about behaviour and nine items about importance were considered in the following analyses.

An analysis of variance was performed with the Generalized Linear Model (GLM) procedure of SAS. The model included region, age, gender, education level and employment situation as fixed effects. Significant differences were determined after applying Tukey test at the level of 0.05. Because of the type of data, the non-parametric Kruskal-Wallis test was also applied by means of the NPAR1WAY procedure of SAS. Because the results of the two tests do not differ significantly the analysis of variance was finally used since it provides more information (O'Mahony, 1986).

To identify the existence of consumer profile segmentation, a hierarchical cluster analysis (Ward method and Euclidian distance) was applied to classify the consumers into homogeneous preference groups. The segmentation and the creation of the clusters was based on the answer given by consumers towards selected items of the questionnaire regarding the most distinctive important aspects related to sustainability (underlined variables in **Table 1**). As a result, a 2-cluster solution was chosen from the dendrogram (for more details see **Figure S1** in supplementary material). The selection of the final number of clusters was aimed at getting the simplest structure possible that still represents homogeneous groupings (parsimony rule). In addition, according to Hair et al. (1998), a balance was made between defining the most basic structure (fewer clusters) that still achieves an acceptable level of heterogeneity between the clusters. GLM procedure, including cluster as fixed effect, was used to determine differences between clusters in the beliefs, importance, and behavioural items studied.

Nonmetric conjoint data was analysed using the TRANSREG procedure of SAS. The model applied considered the monotonic transformation with the sum of all the part-worth utilities for each attribute equal to zero. This is a general and flexible model, usually used in qualitative data. Although the price is numeric, the objective was to include a low and a high price and thus, it has been considered as qualitative in the analysis. The relative importance of each factor and the utility values associated with each level were obtained. The analysis was performed for all the consumers together and for each cluster.

The survey had some shortcomings mainly due to the participants, since in SW regions younger consumers were overestimated and older consumers were underestimated. Moreover, since the survey was part of a wider study (see Garcia-Gudiño et al., 2021), questions were grouped by type in order to simplify the reading.

Table 1a. First and second factors (PC1 and PC2) of the Principal Component Analysis (PCA) by group (beliefs, importance).

	PCA*	**PC1**	**PC2**
Beliefs		*21.7%*	*16.0%*
Sustainable food products are safer than conventional ones and of a higher quality	a	0.75	-0.05
Sustainable food products are higher quality	a	0.68	0.04
Information on sustainable food is poor	b	-0.08	0.90
Information on sustainable food is confuse	b	-0.09	0.88
<u>GMOs are harmful to human health</u>	c	0.75	0.04
<u>Artificial flavours and additives are harmful to human health</u>	c	0.71	0.02
<u>Organic products are too expensive</u>		0.07	0.26
Pesticide residues in fruits and vegetables are harmful to human health		0.44	0.26
I trust little brands in general		0.24	-0.02
I trust white labels		-0.19	0.05
<u>Food from abroad is always better</u>		-0.03	-0.30
Importance		*33.7%*	*12.2%*
<u>When I deal with new products, the brand is important to me</u>		0.22	0.55
The taste of meals is more important than the ingredients		-0.07	0.53
<u>Food packaging is important to me</u>		0.32	0.43
My diet and that of my family are very important to me		0.54	0.18
Given the choice of food products, is it important to you?			
Quality		0.56	0.24
<u>Health care</u>	d	0.64	0.08
<u>Food safety</u>	d	0.58	0.04
<u>Origin in organic farming and livestock</u>		0.63	0.20
<u>Produced locally</u>	e	0.59	0.33
<u>Produced in your own country</u>	e	0.44	0.45
Respect for the environment	f	0.79	-0.31
Recycling	f	0.72	-0.36
Preserving natural resources	f	0.74	-0.37
Environmentally sustainable production	f	0.75	-0.36

*Items with the same letter in the PCA colum were averaged for the analysis. % in italics below PC1 and PC2 is the variance accounted for each principal component. Underlined questions, averaged when they have the same letter in the PCA column, were used to segmented consumers.

Table 1b. First and second factors (PC1 and PC2) of the Principal Component Analysis (PCA) by group (behaviour).

	PCA*	PC1	PC2
Behaviour		*23.1%*	*9.6%*
I generally do not buy products that include preservatives	g	0.62	-0.06
I prefer to buy organic products	g	0.64	0.03
When I deal with new products, I do not usually look at the list of ingredients		-0.32	0.28
I prefer to consume local products that are grown or produced near where I live		0.52	0.61
I usually buy some fair-trade products		0.57	0.20
I do not buy brands or products sold or supplied by companies that are not responsible with the environment and Society		0.56	-0.18
I participate in protests against brands that are not respectful of the environment		0.47	-0.15
I read the labels of the products carefully to know their ingredients, elaboration, contents, calories		0.52	-0.33
I eat organic food because it is a trend and they are fashionable		0.26	0.13
I try to follow a Mediterranean and traditional diet	h	0.52	-0.27
I try to avoid ultra-processed meals	h	0.46	-0.20
I invest more in my health than my look	i	0.52	-0.22
I do exercise regularly	i	0.34	-0.34
When it comes to food, I'm always looking for something new		0.40	-0.09
Every time I eat less meat and side a more vegetarian diet		0.46	-0.24
I try to treat myself every day		0.29	0.09
I prefer food produced locally	j	0.55	0.65
I prefer food from our country	j	0.41	0.52

*Items with the same letter in the PCA colum were averaged for the analysis. % in italics below PC1 and PC2 is the variance accounted for each principal component. Underlined questions, averaged when they have the same letter in the PCA column, were used to segmented consumers.

3. Results

3.1. Questionnaire

A total of 403 respondents completed the questionnaire (19 missing values). Regarding the socio-demographic distributions (see **Table 2**); overall, the study sample was equitable by gender. The age group populations were in line with National Statistics for 2017 except for the elderly subgroup that was slightly underrepresented (INE, 2017). Around 45% of the participants had a university education, a little higher compared to the official figures (EUROSTAT, 2017). Thus, unemployed citizens were underrepresented in the SW subgroup of our study compared to national statistics (INE, 2017) as the sessions were carried out at the university campus.

3.2. Consumers' Knowledge about Sustainability

Most of the respondents (87.4%) indicated that they have heard about the term sustainability before (see **Table 3**). The major differences among clusters were observed at the three main recognized sustainability-related to food consumption attributes 'life quality in daily consumption', 'animal health and welfare' and 'reduction of pesticides and antibiotics'. A higher awareness of the three topics is observed in consumers from Cluster 1 compared to Cluster 2. Consumers of Cluster 1 will be named as consumers with a wide concept of sustainability and consumers from Cluster 2 will be named as consumers with a restricted concept of sustainability. Higher than 21.4% of the respondents do not manage ('no' or 'don´t know' responses) to establish an association of sustainability with animal welfare and/or reduction of antibiotics in both Clusters. Regarding demographic characteristics, the link of sustainability with the environment is lower in consumers with vocational studies (more 'don't know' answers) than those with university education. To highlight, the lower percentage of young consumers (53%) than older ones (79%) involved in this study who agree that one component of sustainability is 'life quality in daily consumption'.

3.3. Consumer beliefs in food products

Consumers from Cluster 1 believe that sustainable food products are safer and of higher quality. Those from Cluster 2 hold the same position but with significantly less prominence. There is a greater belief by Cluster 1 that GMO, artificial flavour, and additives are detrimental to human health meanwhile consumers from Cluster 2 are less concerned with these risks. Both Clusters strongly believe (highest scores of this block) that pesticide residues on food are harmful. Clusters 1 and 2 also believe that organic certified products are too expensive. In addition, Cluster 1 consumers' do not quite agree that foreign food products are better than national products (**Table 4a**).

The most common beliefs are significantly influenced by demographic characteristics such as gender, the region of residence, and education level (presented in **Tables 5a** and **5b**). Women and NE consumers are more aware of the Health' effects of GMO/artificial flavours and the price of organic products ($P < 0.05$). Women and SW consumers are more favourable for local products (than for foreign products) although this is a general agreement by all consumers. Consumers with vocational studies seem to be more satisfied with product label information. Actually, their concerns lie with GMO/artificial flavours compared to consumers with university education. Concerns are generally outstanding for pesticides with no demographic differences. Finally, the trust in white labels is not important for all consumers on this study since the scores are close to neutrality.

3.4. Consumer importance

The most important reasons to purchase sustainable products are family diet, food safety, food quality, and health care. These reasons are highly ranked by consumers from Cluster 1 compared to Cluster 2 (see **Tables 4, 5a** and **5b**). However, all reasons from both Clusters exceed score 4. Cluster 1 gives more importance to organic farming and national and local products than Cluster 2. Cluster 1 also places more importance on product development and product packaging than Cluster 2.

Gender of the responders and the namely region (shown in **Table 5a**) influence consumer importance for buying sustainable products. Men rank product packaging higher than women. Organic products are highly appreciated in NE Spain and local products in the SW region.

3.5. Consumer behaviour

The increasing concerns of society towards the consumption of animal products, and how they have been produced, were also studied in this survey by discriminating into product differentiation: new, local, fair trade, and environmentally friendly products (see **Tables 4b, 6a** and **6b**).

In our study, cluster 1 buys more products without preservatives and more organic products (**Figure 1**). Cluster 1 cares more about fair trade, local products and tries to follow a traditional Mediterranean diet avoiding ultra-processed food. Cluster 1 also invests more in health, does exercise more regularly, consumes less meat, and focus on vegetarian options.

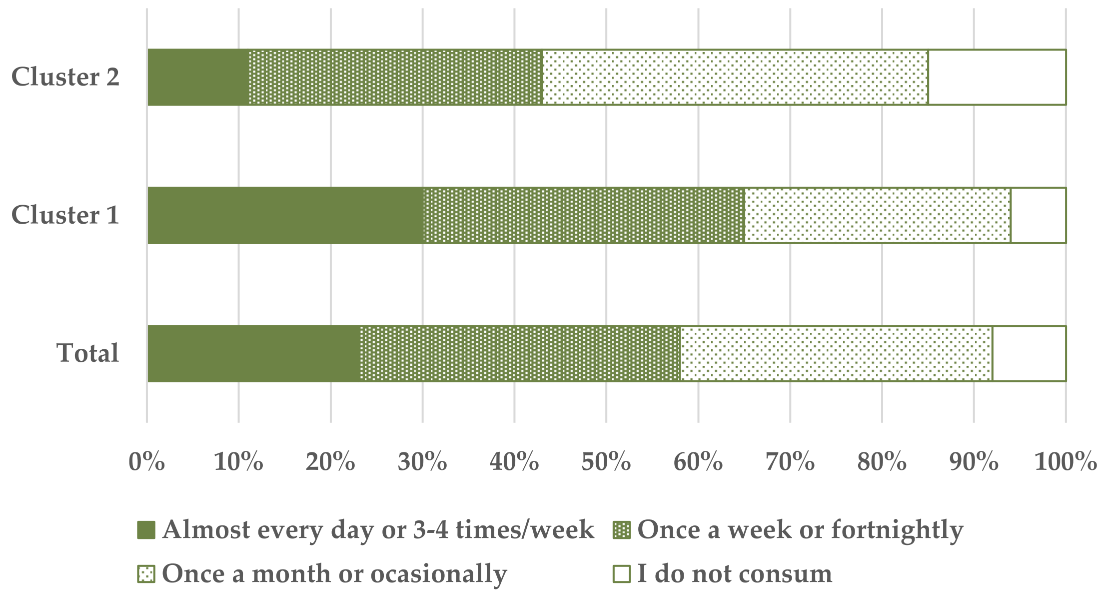

Figure 1. Frequency of consumption of organic food by cluster and overall sample of participant consumers. Different letters between clusters and frequencies indicate significant differences (P<0.05).

Consumer behaviour is influenced by the region of residence, age group, and gender (P < 0.05) (see **Table 6a**). Trust on food labels does not show significant differences by demographic characteristics. The education level and employment do not constitute any influence on consumer preference.

The other lifestyle brands and product packaging are scored differently by region of residence, age, or gender (P < 0.05) (see **Table 6a**). NE consumers rank higher investing in health, sport, and novel products seeking. Meanwhile respondents from SW show a higher appreciation for local products (average score 4.3). In addition, the youth generation gives a significantly higher ranking (P < 0.05) of new products and eats treats every day. Women give more importance to the Mediterranean diet and to a decreased consumption of ultra-processed food. Consumers with university education rank higher to eat less meat and more plant-based foods (P< 0.01). On the contrary, the young consumers in this study with basic studies consider more important to eat treats daily.

3.6. Grocery shopping patterns

The shopping place is the most important difference in analysed buying habits between Clusters (for more details see **Table S2** in supplementary material). Consumers from cluster 1 buy more in the food market (as a general practice) and in local butchers, and avoid (plastic) packaging in comparison with those from Cluster 2. There is a slight difference in the consumption of pork meat or meat products between Clusters. More frequent consumption of Iberian pork was shown in Cluster 1, but it was not statistically more frequent, occasional eating, on the other hand, was declared by a statistically higher percentage from Cluster 2. For processed Iberian pork, no significant differences were found. Besides, Cluster 1 gives greater importance to purchase choice and more specifically to what they perceive as a more sustainable choice (less packaging, more local trade, and local markets).

Table 2. Sociodemographic characteristics of the participant consumers by region and clusters obtained through non-hierarchical cluster analysis.

	Global (n=403)	**NE (n=201)**	**SW (n=202)**	**Cluster 1* (n=276)**	**Cluster 2* (n=125)**
Area					
Northeast	50.62	-	-	55.43	38.40
Southwest	49.38	-	-	44.57	61.60
Age group					
< 25	19.35	8.50	29.35	13.77	32.00
25-40	27.05	29.00	25.37	25.72	30.40
40-60	40.45	42.50	38.81	44.20	32.00
> 60	13.15	20.00	6.47	16.30	5.60
Gender					
Men	49.38	47.76	50.99	47.83	53.60
Women	50.62	52.24	49.01	52.17	46.40
Education level					
Basic studies	26.87	29.50	17.41	27.64	25.60
University	44.28	33.50	61.19	42.18	48.80
Vocational education	28.86	37.00	21.39	30.18	25.60
Employment situation					
Student	22.33	9.95	34.65	17.39	33.60
Self-employed	4.96	6.47	3.47	5.43	4.00
Public official	24.32	5.47	43.07	23.55	25.60
Retired	9.43	15.42	3.47	11.96	3.20
Employee	34.49	55.22	13.86	37.32	28.80
Unemployed	4.47	7.46	1.49	4.35	4.80

*Two consumers were not considered in the clusters due to mising values in some of the segmetiton questions.

Table 3. Consumers' knowledge (in %) about sustainability by clusters and the global sample obtained through non-hierarchical cluster analysis.

	Yes			No			Do not know		
	Global	**Cluster1**	**Cluster2**	**Global**	**Cluster1**	**Cluster2**	**Global**	**Cluster1**	**Cluster2**
Have you ever heard about sustainability?	87.44	86.80	88.70	4.27	4.80	3.20	8.29	8.50	8.10
What is the meaning for you of sustainability related to food?									
Integration of natural habitat conservation with the survival of the economic system	83.13	84.10	81.60	4.71	4.40	5.60	12.16	11.60	12.80
Be aware of the quality of life in daily consumption decisions	66.25	73.6[a]	50.4[b]	17.87	14.90	24.80	15.88	11.60[b]	24.80[a]
Ensure the health and welfare of animals	78.61	82.90	68.80	13.43	9.50[b]	22.40[a]	7.96	7.60	8.80
Conservation and protection of water resources	71.71	72.10	70.40	8.68	8.00	10.40	19.60	19.90	19.20
Reduction or elimination of pesticides and antibiotics in livestock and agriculture	78.16	82.30	68.80	9.43	6.90[b]	15.2[a]	12.41	10.90	16.00

Different letters between clusters and within answers (yes, no, do not know) indicate significant differences ($P<0.05$).

Table 4a. Description of the clusters of consumers' beliefs, importance, and behaviour related to sustainable food production aspects and relative importance of each characteristic[1].

	Cluster 1 (n=276)	**Cluster 2 (n=125)**	**RMSE***	**p-value**
Beliefs				
Sustainable food products are safer than conventional ones and of a higher quality	3.8	3.3	0.83	**<0.001**
Information on sustainable food is poor and confusing	4.0	4.0	0.98	0.4200
GMOs, artificial flavors and additives are harmful to human health	3.9	2.9	0.99	**<0.001**
Organic products are too expensive	4.2	3.9	0.96	**0.0072**
Pesticide residues in fruits and vegetables are harmful to human health	4.6	4.4	0.85	0.0161
I trust little brands in general	3.2	3.0	1.07	0.1226
I trust white labels	3.3	3.4	0.99	0.0946
Food from abroad is always better	1.7	1.5	0.80	**0.0261**
Importance				
When I deal with new products, the brand is important to me	3.6	3.0	1.17	**<0.001**
The taste of meals is more important than the ingredients	2.6	2.4	1.21	0.1411
Food packaging is important to me	3.9	3.5	0.99	**0.0004**
My diet and that of my family are very important to me	4.8	4.3	0.57	**<0.001**
Given the choice of food products, is it important to you?				
Quality	4.7	4.4	0.54	**<0.001**
Health care and food safety	4.6	4.3	0.61	**<0.001**
Origin in organic farming and livestock	3.8	2.8	0.99	**<0.001**
Produced locally or in your own country	4.3	3.3	0.82	**<0.001**
Respect for the environment, recycling, preserving natural resources and sustainable production	4.5	4.0	0.65	**<0.001**

[1] Five-point likert agreement scales from 1: completely disagree to 5: fully agree.
*RMSE: root mean squared error.

Table 4b. Description of the clusters of consumers' beliefs, importance, and behaviour related to sustainable food production aspects and relative importance of each characteristic[1].

	Cluster 1 (n=276)	Cluster 2 (n=125)	RMSE*	p-value
Behaviour				
I generally do not buy products that include preservatives, preferring to buy organic food	3.3	2.4	0.86	**<0.001**
When I deal with new products, I do not usually look at the list of ingredients	2.2	2.6	1.30	**0.004**
I prefer to consume local products that are grown or produced near where I live	4.3	3.5	0.93	**<0.001**
I usually buy some fair-trade products	3.5	2.4	1.09	**<0.001**
I do not buy brands or products produced or manufactured by companies that are not responsible with the environment and society	3.3	2.3	1.08	**<0.001**
I participate in protests against brands that are not respectful of the environment	2.2	1.7	1.11	**<0.001**
I read the labels of the products carefully to know their ingredients, elaboration, contents, calories	3.8	3.3	1.16	**<0.001**
I eat organic food because it is a trend and they are fashionable	2.0	1.5	0.95	**<0.001**
I try to follow a Mediterranean and traditional diet, avoiding ultra-processed meals	4.3	3.5	0.76	**<0.001**
I do exercise regularly investing more in my health than my look	3.9	3.3	0.80	**<0.001**
When it comes to food, I'm always looking for something new	3.4	2.9	1.10	**<0.001**
Every time I eat less meat and I focus on a more vegetarian diet	3.0	2.1	1.28	**<0.001**
I try to treat myself every day	3.0	2.6	1.16	**0.010**
I prefer food produced locally or from our country	4.5	3.7	0.73	**<0.001**

[1] Five-point likert agreement scales from 1: completely disagree to 5: fully agree.
*RMSE: root mean squared error.

Table 5a. Least squared mean value[1] on consumers' beliefs and importance related to sustainable food production aspects and relative importance of each demographic characteristics.

	Area*		Age group*				Gender*					
	NE	**SW**	**1**	**2**	**3**	**4**	**M**	**W**	**RMSE**	**Area**	**Ag**	**G**
Beliefs												
Sustainable food products are safer than conventional ones and of a higher quality	3.8	3.6	3.8	3.8	3.8	3.6	3.7	3.8	0.86	**0.077**	0.615	*0.056*
Information on sustainable food is poor and confusing	3.9	4.0	4.1	4	3.8	3.8	3.9	4.0	0.98	0.385	0.587	0.186
GMOs and artificial flavors and additives are harmful to health	3.8^{a}	3.5^{b}	3.3	3.8	3.7	3.7	3.5^{b}	3.8^{a}	1.02	**0.040**	0.132	**0.001**
Organic products are too expensive	4.2^{a}	3.9^{b}	4	4.1	4.1	4.1	3.9^{b}	4.2^{a}	0.94	**0.022**	0.982	**0.003**
Pesticide residues in fruits and vegetables are harmful to human	4.6	4.5	4.4	4.5	4.5	4.7	4.5	4.6	0.86	0.733	0.547	0.517
I trust little brands in general	3	3.2	2.9	3.2	2.9	3.2	3.1	3.1	1.08	0.164	0.501	0.904
I trust white labels	3.3	3.3	3.1	3.2	3.1	3.6	3.2	3.3	0.98	0.940	0.214	0.160
Food from abroad is always better	1.9^{a}	1.5^{b}	1.8	1.7	1.6	1.6	1.8^{a}	1.6^{b}	0.77	**<0.001**	0.764	**0.008**
Importance												
When I deal with new products, the brand is important to me	3.7	3.4	3.5	3.4	3.4	3.9	3.6	3.4	1.15	*0.053*	0.185	*0.089*
The taste of meals is more important than the ingredients	2.7	2.6	2.8	2.5	2.5	2.8	2.7	2.6	1.18	0.356	0.607	0.413
Food packaging is important to me	3.7^{b}	4.0^{a}	3.8	3.8	3.8	4.1	4.0^{a}	3.7^{b}	1.00	**0.024**	0.509	**0.023**
My diet and that of my family are very important to me	4.7	4.6	4.5	4.6	4.7	4.8	4.6	4.7	0.60	0.232	0.255	0.351
Given the choice of food products, is it important to you?												
Quality	4.7	4.6	4.7	4.5	4.6	4.7	4.6	4.6	0.55	0.446	0.276	0.948
Health care and food safety	4.6	4.5	4.5	4.4	4.5	4.7	4.5^{b}	4.6^{a}	0.61	*0.067*	*0.061*	**0.009**
Origin in organic farming and livestock	3.8^{a}	3.4^{b}	3.7	3.6	3.6	3.5	3.6	3.6	1.09	**0.011**	0.925	0.591
Produced locally or in the country	3.9^{b}	4.1^{a}	3.6	4.1	4.1	4.2	4.0	4.0	0.93	**0.043**	0.150	0.525
Respect for the environment, recycling, preserving natural resources and sustainable production	4.4	4.4	3.6	4.1	4.1	4.2	4.0	4.0	0.68	0.678	0.937	*0.093*

*Area: NE: Northeast, SW: Southwest; Age group (Ag): 1) <25 years, 2) 25-40 years, 3) 40-60 years, 4) >60 years; Gender (G): M: Men, W: Women.

[1] Likert scales from 1: completely disagree to 5: fully agree. RMSE: root mean squared error.

Table 5b. Least squared mean value[1] on consumers' beliefs and importance related to sustainable food production aspects and relative importance of each demographic characteristics.

	Education*			**Employment***								
	Bs	**Un**	**V**	**St**	**S**	**P**	**R**	**E**	**U**	**RMSE**	**Ed**	**Em**
Beliefs												
Sustainable food products are safer than conventional ones and of a higher quality	3.7	3.7	3.8	3.6	3.9	3.6	3.8	3.6	4	0.86	0.577	0.349
Information on sustainable food is poor and confusing	4.0[ab]	4.1[a]	3.7[b]	3.7	3.7	4.1	3.9	4	4	0.98	**0.028**	0.541
GMOs and artificial flavors and additives are harmful to health	3.8[a]	3.4[b]	3.7[ab]	3.2	3.5	3.7	3.7	3.6	4	1.02	**0.013**	0.195
Organic products are too expensive	4.1	4.1	4.1	4	4.4	4.1	4	4.1	4	0.94	0.728	0.693
Pesticide residues in fruits and vegetables are harmful to human	4.6	4.6	4.4	4.7	4.6	4.7	4.1	4.5	4.7	0.86	0.212	0.114
I trust little brands in general	3.2	3	3.2	3.1	3.2	3.2	3.2	3.1	2.8	1.08	0.217	0.886
I trust white labels	3.3	3.3	3.1	3.6	3.1	3.5	3.1	3.3	3	0.98	0.252	0.199
Food from abroad is always better	1.7	1.6	1.8	1.7	1.7	1.5	1.8	1.5	1.8	0.77	0.252	0.463
Importance												
When I deal with new products, the brand is important to me	3.4	3.5	3.6	3.3	3.6	3.3	3.6	3.5	3.8	1.15	0.185	0.388
The taste of meals is more important than the ingredients	2.7	2.4	2.8	2.2	2.8	2.5	2.8	2.9	2.6	1.18	0.607	*0.060*
Food packaging is important to me	4	3.8	3.9	3.8	4	3.7	3.7	4	4	1	0.509	0.377
My diet and that of my family are very important to me	4.6	4.6	4.7	4.6	4.7	4.6	4.6	4.6	4.8	0.6	0.255	0.714
Given the choice of food products, is it important to you?	4.6	4.6	4.7	4.6	4.6	4.6	4.7	4.6	4.7	0.55	0.276	0.171
Quality												
Health care and food safety	4.5	4.5	4.6	4.6	4.4	4.6	4.4	4.5	4.7	0.61	*0.061*	0.337
Origin in organic farming and livestock	3.5	3.5	3.7	3.4	3.7	3.4	3.8	3.5	3.8	1.09	0.925	0.360
Produced locally or in the country	3.9	4	4.1	4	4.1	3.8	4.1	3.9	4	0.93	0.150	0.502
Respect for the environment, recycling, preserving natural resources and sustainable production	4.3	4.4	4.4	4.4	4.2	4.3	4.5	4.3	4.7	0.68	0.937	0.393

*Education (Ed): Bs: Basic studies, Un: University, V: Vocational; Employment (Em): St: Student, S: Self-employment, P: Public official, R: Retired, E: employee, U: unemployed; RMSE: root mean squared error. [1] Likert scales from 1: completely disagree to 5: fully agree.

Table 6a. Least squared mean value[1] rates of the behaviour related to sustainable food production aspects by demographic characteristics of the participant consumers.

	Area*		**Age group***				**Gender**					
	NE	**SW**	**1**	**2**	**3**	**4**	**M**	**W**	**RMSE**	**Area**	**Ag**	**G**
I generally do not buy products that include preservatives, preferring to buy organic food	3.2	2.9	2.7	3.2	3.1	3.2	3.0	3.1	0.93	*0.065*	0.120	0.208
When I deal with new products, I don't usually look at the information on the label	2.2^{b}	2.6^{a}	2.7	2.1	2.4	2.3	2.6^{a}	2.2^{b}	1.30	**0.014**	0.165	**0.004**
I prefer to consume local products that are grown or produced near where I live	3.9^{b}	4.3^{a}	3.8	4.0	4.2	4.4	4.1	4.1	1.00	**0.013**	0.336	0.863
I usually buy some fair-trade products	3.2	3.1	2.6^{b}	3.3^{a}	3.1^{ab}	3.6^{a}	3.1	3.2	1.18	0.272	**0.004**	0.734
I do not buy brands or products produced or manufactured by companies that are not responsible with the environment and society	3.1	2.9	2.5^{b}	3.0^{ab}	3.3^{a}	3.2^{ab}	2.9^{b}	3.1^{a}	1.13	0.318	**0.048**	**0.045**
I participate in protests against brands that are not respectful of the environment	2.3	2.1	2.3	2.1	2.1	2.1	2.1	2.2	1.14	0.181	0.826	0.603
I read the labels of the products carefully to know their ingredients, elaboration, contents, calories...	3.7	3.6	3.3	3.8	3.7	3.8	3.6	3.7	1.18	0.524	0.210	0.199
I eat organic food because it is a trend and they are fashionable	2.0	1.8	1.6	2.0	2.1	1.9	1.9	1.9	0.94	0.167	0.223	0.481
I try to follow a Mediterranean and traditional diet, avoiding ultra-processed meals	4.1	4.0	3.8	4.0	4.2	4.3	3.9^{b}	4.2^{a}	0.81	0.146	*0.086*	**0.010**
I do more exercise for my health than for my look	3.8^{a}	3.2^{b}	3.0	3.5	3.5	3.9	3.6	3.4	1.14	**<0.001**	*0.089*	0.266
When it comes to food, I'm always looking for something new	3.4^{a}	3.1^{b}	3.5^{ab}	3.6^{a}	3.2^{b}	2.8^{b}	3.3	3.3	1.10	0.025	**0.007**	0.799
Every time I eat less meat and I focus on a more vegetarian diet	2.8	2.9	2.6	2.6	2.9	3.2	2.7	2.9	1.27	0.612	0.194	**0.086**
I try to treat myself every day	3.0	2.8	2.6^{b}	3.2^{a}	2.9^{ab}	2.9^{ab}	2.9	2.9	1.15	0.227	**0.013**	0.561
I prefer food produced locally or from our country	4.2^{b}	4.6^{a}	4.2	4.4	4.5	4.6	4.3	4.5	0.86	**0.003**	0.586	*0.064*

*Area: NE: Northeast, SW: Southwest; Age group: (Ag): 1)<25 years, 2)25-40 years, 3)40-60 years, 4)>60 years; Gender (G): M: Men, W: Women. [1] Likert scales from 1: completely disagree to 5: fully agree. RMSE: root mean squared error

Table 6b. Least squared mean value[1] rates of the behaviour related to sustainable food production aspects by demographic characteristics of the participant consumers.

	Education*			Employment*							
	Bs	**Un**	**V**	**St**	**S**	**P**	**R**	**E**	**U**	**RMSE**	**Ed**	**Em**
I generally do not buy products that include preservatives, preferring to buy organic food	3.1	3.0	3.0	3.0	2.9	3.0	3.2	2.9	3.3	0.93	0.511	0.567
When I deal with new products, I don't usually look at the information on the label	2.4	2.4	2.4	2.1	2.3	2.0	2.7	2.6	2.6	1.30	0.956	0.088
I prefer to consume local products that are grown or produced near where I live	4.1	4.2	4.1	4.3	4.3	4.1	3.9	4.0	4.1	1.00	0.700	0.761
I usually buy some fair-trade products	3.2	3.1	3.2	3.5	3.2	3.2	2.8	3.1	3.3	1.18	0.663	0.559
I do not buy brands or products produced or manufactured by companies that are not responsible with the environment and society	3.1	2.9	3.0	3.0	2.5	2.9	3.2	2.9	3.4	1.13	0.473	0.236
I participate in protests against brands that are not respectful of the environment	2.0	2.3	2.2	1.7	1.9	2.1	2.3	2.1	2.8	1.14	0.268	0.078
I read the labels of the products carefully to know their ingredients, elaboration, contents, calories...	3.8	3.6	3.6	3.8	3.5	3.7	3.9	3.5	3.5	1.18	0.352	0.525
I eat organic food because it is a trend and they are fashionable	1.8	1.9	2.0	1.7	2.3	1.7	1.8	1.8	2.1	0.94	0.516	0.088
I try to follow a Mediterranean and traditional diet, avoiding ultra-processed meals	4.1	4.1	4.0	3.9	4.0	4.1	4.2	4.0	4.0	0.81	0.502	0.936
I do more exercise for my health than for my look	3.3	3.6	3.6	4.1[a]	3.1[b]	3.8[ab]	3.2[ab]	3.4[ab]	3.4[ab]	1.14	0.102	**0.029**
When it comes to food, I'm always looking for something new	3.3	3.2	3.2	3.2	3.1	3.2	3.3	3.2	3.5	1.10	0.802	0.887
Every time I eat less meat and I focus on a more vegetarian diet	2.8[b]	3.2[a]	2.6[b]	2.3	3.2	2.6	3.1	2.7	3.1	1.27	**0.001**	0.129
I try to treat myself every day	3.1[a]	2.7[b]	2.9[ab]	3.1	2.7	2.8	2.8	2.8	3.0	1.15	**0.037**	0.874
I prefer food produced locally or from our country	4.4	4.3	4.4	4.4	4.5	4.2	4.5	4.5	4.4	0.86	0.684	0.726

* Education (Ed): Bs: Basic studies, Un: University, V: Vocational; Employment (Em): St: Student, S: Self-employment, P: Public official, R: Retired, E: employee, U: unemployed; RMSE: root mean squared error. [1] Likert scales from 1: completely disagree to 5: fully agree.

3.7. Consumer preference

The conjoint analysis shows that preferences from the utilities differ by Clusters (see **Table 7**). Breed type and production system are the most preferred attributes and differ significantly with price in Cluster 1. The difference among attributes in Cluster 2 is less remarkable. The price is most important for Cluster 2 giving lower importance to the production system compared to Cluster 1.

Table 7. Relative importance and utility values of each factor of the conjoint analysis for Spanish consumers in the global sample and by cluster obtained through non-hierarchical cluster analysis.

	Global	**Cluster 1**	**Cluster 2**
n	403	294	109
Intercept	4.5	4.5	4.5
Breed			
White pig	-1.18	-1.17	-1.20
Iberian pig	1.18	1.17	1.20
Relative importance (%)	42.61	43.63	40.12
Production System			
Extensive	1.09	1.14	0.99
Intensive	-1.09	-1.14	-0.99
Relative importance (%)	39.34	42.49	33.04
Price			
7€/kg	0.50	0.37	0.81
12€/kg	-0.50	-0.37	-0.81
Relative importance (%)	18.05	13.88	26.84
RMSE*	1.55	1.56	1.48
R^{2*}	0.54	0.54	0.59

*RMSE: root mean square error; R^2: coefficient of determination.

3.8. Research limitations

This study has two main limitations detailed in Garcia-Gudiño et al. (2021) since are part of the same study. In brief, the primary limitation is a bias in the sample of participant consumers, especially in the SW region. As explained before, the young consumers were over-represented and this could have bias the results since the age has been significant in some questions. Biases in other consumers's characteristics such as the high number of consumers with a high educational level, the high number of public employees and the low percentage of unemployed consumers might affect in a lower degree since they have less importance in the responses. Larger studies should be executed because the samples of respondents on this study was small, while identifying typologies requires research on representative samples.

Another shortcoming is related to the layout of the questionnaire. Because the questionnaire was part of a wider study, questions were grouped by blocks to simplify the reading and, consequently, reduce the fatigue in answering the questionnaire.

4. Discussion

4.1. Consumers' Knowledge about Sustainability

Sustainability is seen by most consumers of this study as poor and confusing. In this study, although more than 85% of the consumers have heard about sustainability, the meaning of sustainability-related to food is heterogeneous. Our results are consistent with the results of other studies (Laureati et al., 2013) which indicate that the sustainability concept keeps confused in people's minds since consumers don´t understand the idea of sustainable consumption (Rejman et al., 2019). Yet, sustainability should be better integrated into the Spanish Dietary Guidelines to promote citizens' awareness (Rejman et al., 2019).

The components of sustainability that were considered most relevant by consumers (natural habitat conservation, assuring animal health and welfare, and reduction of pesticides and antibiotics) are frequently mentioned in European surveys. Spanish consumers' concerns about farm animal welfare can prevent them from buying some products from intensive systems but their perceptions and concerns to make more informed decision to improve their sustainability is pending (Rejman et al., 2019). Environmental concerns are increasingly top of mind for consumers, as well as the willingness to pay for environmentally friendly products (Kaczorowska et al., 2019; Peschel et al., 2016). Consumers perceive that the welfare of farmed animals should be better protected (European Commission, 2016), despite the fact (at the same time) of their lack of knowledge of intensive farming practices and understanding of welfare problems in intensive production including Spain (Alonso et al., 2020; Clark et al., 2019). Present results show that a substantial percentage of consumers do not know or do not consider the quality of life in daily consumption decisions and less likely on animal welfare as part of sustainability, being these proportions higher on Cluster 2 (consumers with a restricted concept of sustainability). The last Eurobarometer (European Commission, 2019) highlighted the misuse of antibiotics, hormones, and steroids in farm animals, pesticide residues in food, and food additives. Safe warding of antibiotics paves the way to reduce the threat of AMR that critically affects the ability to achieve the SDGs agenda. According to Jørgensen et al. (2020), efforts to curb antibiotic and pesticide resistance are particularly linked to SDG 3 (Good health and well-being) and SDG 12. The highest global antimicrobial consumption takes place in the food production animal sector found in countries like China, India, USA, Brazil, and some European countries including Spain where antimicrobial consumption in pork production is largely concentrated in the NE region of Spain (Van Boeckel et al., 2015). Therefore, it is important to assess the sustainability of antimicrobial use in animal agriculture and regulate it on a global and regional scale for the sake of both human and animal health (Lhermie et al., 2019).

4.2. Main finding on sustainable food consumption

Little is known about how consumers' understanding of sustainability is manifested in consumption decisions. Such segmentation provides a relevant reflection of the actual state of mind of the Spanish consumers. It might help to find approaches to consumers through information, co-educational plans, and effective marketing strategies.

In some previous studies on consumer segments, extrinsic factors, such as product origin, and other related aspects such as the production system or the environmental impact of manufacturing processes, were relevant elements in consumer purchasing decisions (Font-i-Furnols et al., 2006, 2019; Troy & Kerry, 2012; Vitale et al., 2020). In the present study, product origin was one of the most relevant drivers (which also contributes to differentiating the two Clusters) influencing purchasing decisions. The consumer of this study, more significantly from Cluster 1, does not perceive food products that come from abroad as better products. At the same time, the consumer valued positively local and/or national products. Preferences on product origin have been widely related to perceived quality (Papanagiotou et al., 2013), food security (Kim, 2007), and decrease environmental impacts (Grunert et al., 2004). Therefore, it is seen as an important determinant of quality and as a way to support local producers (Vitale et al., 2020). A differentiated pattern is observed in the two regions under study in the present work. SW consumers are more supportive of local products which could be associated with a greater understanding and familiarity with the livestock activity (more popular in this region) or the sense of localness compared to consumers from NE Spain. This sociodemographic differentiator has been shown to impact risks perceptions, benefits, and farm animal welfare elsewhere (Clark et al., 2019), and it is especially linked to SDG 2 (use local products) and SDG 12 (responsible consumption and production).

In general, consumers of this study have an environmental sensitivity to the issues of production and responsible consumption showing foremost importance in factors such as the environment, recycling, conservation of natural resources at the promotion of sustainable production. These results are in line with Spanish society's awareness of the detrimental effects of intensive livestock systems (European Commission, 2016). Many respondents agree with the statement that sustainable food products are safer and of better quality than conventional ones. The results showed a consumer in charge of family diet with high awareness of health impact of pesticides, use of GMOs, flavourings, and artificial additives. A consumer who tries to follow a Mediterranean diet avoiding ultra-processed food products. There is a reluctance to the price of organic products that continues to be a barrier to shopping these products. López-Galán et al. (2013) indicated that neither social norms nor consumers' concerns on health and environment affect the intention to purchase organic food in Spain, but the price. In fact, the greater explanatory power of the purchase intention for organic products on previous studies is to be the price. High prices are perceived as the biggest barrier for more than 40% of European respondents in other studies (Eldesouky et al., 2020; Napolitano et al., 2009). Consumers with a deeper concept of sustainability (Cluster 1) seem to be less affected by meat price, as can be seen in the results of the conjoint analysis (**Table 7**) and shopping practices (**Figure 1**). Previous studies argued that a segment of potential consumers of organic food could be expanded if it is possible to increase the level of consumer's knowledge about these products (Soler et al., 2002). However, in the Spanish context, there are more factors influencing purchasing decisions, such as the income, the education level, and consumers' environmental consciousness (López-Galán et al., 2013).

It is clear that branding is an essential factor in consumer's purchasing decisions (Eldesouky et al., 2020). Brand name has a strong influence on perceived quality and consumer buying behaviour in the organic food market (Rana & Paul, 2017). In this sense, the consumption of fair trade products has been gaining acceptance due to the growing interest in business ethics (Eldesouky et al., 2020). Tools that reduce the negative impact of food companies on labour, social and environmental rights, stimulate producers and consumers to produce and consume more sustainably, respectively (Kirezli & Kuşcu, 2012). However, on the basis of the results of the present study, fair trade products are not yet well known by consumers. There is a high percentage of consumers who punish food companies for not investing in Corporate Social Responsibility or claiming environment-friendly procedures (Diaz Carmona, 2019). Although the figures for this study show that youth can lead the way to sustainable consumption, the adoption of ethical consumption by Spanish consumers remains low (Diaz Carmona, 2019).

In the conjoint analysis, the equal importance to breed (siding local breeds) and production system (pro-extensive system preference) of Cluster 1, line up with more sustainable production. Production of traditional food products, are often closely related to less intensive production systems that typically rely on local resources and, as such, play important roles in the conservation of agroecosystems including local livestock breeds (Vitale et al., 2020). In fact, by putting the two frequencies together, consumers from Cluster 1 have a good image of the Iberian pig as elsewhere reported (Rodríguez-Estévez et al., 2009,2011). The influence of the information on the local production on consumer expectations was also reported by Vitale et al. (Vitale et al., 2020). Cluster 2 gives greater importance to the breed (Iberian) than to the production system. This difference in Cluster 2 could be explained suggests that the predilection towards Iberian products is based on the quality of these products (extra sensorial and nutritional qualities) as suggested by other researchers (Francisco J. Mesías et al., 2013), and less arguably by the traditional husbandry (Díaz-Caro et al., 2019; Mesías et al., 2010). In general, price is the least important attribute assigned by consumers in the study. Thus, the consumption of pork products in these groups (shopping practices) agrees with the results of the conjoint analysis. While there are no differences in consumption between Clusters when it comes to meat or pork generic products (cheaper products), it is however observed in those from Iberian pigs. Economic factors, more than food sustainability characteristics, are commonly considered by the population. Consumers from Cluster 1 are consuming expensive products more often. Although consumers from both Clusters prefer cheaper prices, Cluster 1 gives less importance to the price, consuming more of Iberian products. It is also worth noting that the majority of the population has in mind that Iberian products are "more sustainable" because they have the image of the pig in the pasture (Rodríguez-Estévez et al., 2009), when most of the Iberian production is intensive (65%) and only one third is reared under extensive management (RIBER, 2020).

The ever-changing perspectives on how consumers shop and embrace social causes in alignment with their personal values are the reason to combine consumer preference and shopping practices in this study. The results were the most coherent possible by accounting for their preference in the analysis of the shopping practices of animal products of this study. Consumers from Cluster 1 are adopting more sustainable practices by going to the local butchers and markets and escaping from packaged food. They often buy Iberian pork products and less often pork products. However, it is also true the Cluster 2 is built up with consumers with a less expanded concept of sustainability. Consumers concerned about ethical, environmental, and health issues and with a "local" orientation in the food market are more likely to buy organic food (Torjusen et al., n.d.), as observed in this study. These social considerations may provide a basis for identifying common goals to further develop the organic food system.

By analysing the influence of demographic characteristics in this study, the place of residence has brought the most remarkable differences that might require the strengthening of food system urban-rural linkages. Thus, cultural diversity and the urban model of citizens (more specifically in the NE region) should be considered by policymakers since it can be relevant when developing marketing strategies. Second, the age of the consumers requires special attention (and consequently implications on educative programs). The research focused on analysing the attitudes and behaviours of this segment is still extremely limited and above all in Spain. Nevertheless, the findings are of great importance for all those agents (NGOs, companies, and public powers) interested in promoting ethical consumption. The young consumers were chosen since they are more sensitive to the current trends as well as they are the foundation for future market development. Efforts should, therefore, be taken to transfer knowledge in the next generations, creating conscious and ethical consumers. Regarding the significance of treats every day on young people in this study, consumers are now driven by "micro-needs" that reveal their desires for specific products or attributes that conform to what they consider important or valuable. Third, women show a more pro-healthy diet and safe product behaviour in their consumption decisions. Although significant differences were only observed in some behaviours, it is important to mention that in Spain still today, women are in charge of most of the food shopping (Achón et al., 2017) and cooking at home. Finally, it is quite astonishing the lack of heterogeneity (significant associations) in terms of education level throughout the different outcomes explored. Even though current societies are, the most developed and informed, there is still uncertainty about what specific dietary recommendations should be followed (Achón et al., 2017). González-García et al. (2020) claimed the incorporation not only of health but also of environmental indicators on dietary options in the Spanish national dietary guidelines to promote their adhesion to balance and sustainable dietary habits.

5. Conclusions

In the context of the present study, it is possible to conclude that, although most of the consumers have heard about sustainability, they are not aware of the ampleness of the concept. The awareness of those terms is a necessary condition for changes in consumers' behaviours and consumption models. Several factors limit the transformation progress of consumer into sustainable diet-purchase decisions and practice. The main barriers preventing the transition of sustainability values into actions seem to be education and information. The framework of the Iberian pig production still manifests a low knowledge of the farm system attributes that are drivers to make it more sustainable. In this pork case study, policy-makers play, or should play, a key role as mediators and in defining quality standards in favor of social sustainability (in particular, fairness and transparency in the production chain (regarding the veracity of the production and feeding system in the final life of the animal)) and clarity for the consumer.

It is noteworthy to highlight the influence of the education level in knowledge (concepts and components) of sustainability. Information campaigns and a greater focus on education can raise awareness about the concept of sustainability among consumers, which will influence sustainable food purchases. Educational strategies (information campaigns and nutritional education programs among citizens) should be considered to involve more consumers in taking care of sustainability. A better understanding of livestock practices and linkages with ethical and ecological implications (and not only on nutritional aspects and better-tasting).

For the sake of the creation of a social environment that makes it easier to choose healthy and sustainable diets as part of sustainable food consumption of SDG 12, it is advisable to provide information to make sustainable choices and demonstrate specific behaviours that can be easily adopted and integrated on consumer daily habits. It is also important to empower consumers towards responsible consumption, more specifically to the youth generation.

Further research is needed to go more in deep in the study of the dimensions of sustainability and its relation to different aspects of production systems.

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Supplementary Material

Table S1. Questionnaire and selected questions to perform the cluster analysis.

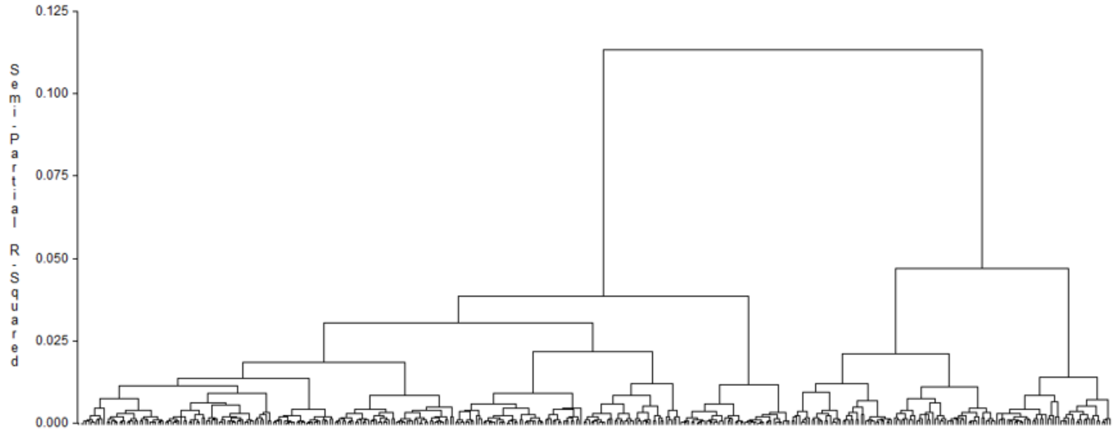
N. question	Question Description
KNOWLEDGE IN SUSTAINABILITY	
P10	*Have you ever heard of sustainability?*
P11	*What is the meaning for you of sustainability related to food? Indicate if you agree with the following statements:*
P11_1	The integration of natural habitat conservation with the survival of the economic system
P11_2	Be aware of the quality of life in daily consumption decisions
P11_3	Ensure the health and welfare of animals
P11_4	Conservation and protection of water resources
P11_5	Reduction or elimination of pesticides and antibiotics in livestock and agriculture
P14	*Indicate how much do you agree with the following statements:*
P14_8	I know the difference between an organic product and a natural, healthy or crop garden product
BELIEFS	
P12	*Taking into account sustainable food products, please indicate how much you agree with the following statements:*
P12_12	I believe that sustainable food products are safer than conventional ones and of a higher quality
P12_34	Information on sustainable food is poor and confusing
P13	*Indicate how much you agree with the following statements:*
P13_4	I think organic products are too expensive
P13_7	Pesticide residues in fruits and vegetables are harmful to human health
P13_89	GMOs and artificial flavors and additives are harmful to human health
P14	*Indicate how much you agree with the following statements:*
P14_3	I trust little brands in general
P14_4	I trust white labels
P19	*Indicate how much you agree with the following statements:*
P19_3	Food from abroad is always better
BEHAVIOUR	
P13	*Indicate how much you agree with the following statements:*
P13_16	I generally do not buy products that include preservatives, preferring to buy organic food
P13_2	When I deal with new products, I don't usually look at the list of ingredients
P14	*Indicate how much you agree with the following statements:*
P14_1	I prefer to consume local products, that are grown or produced near where I live
P14_2	I usually buy some fair trade products
P14_5	I do not buy brands or products produced or manufactured by companies that are not responsible with the environment and society
P14_6	I participate in protests against brands that are not respectful of the environment
P14_7	I read the labels of the products carefully to know their ingredients, elaboration, contents, calories ...
P14_9	I eat organic food because it is the trend and they are fashionable
P15	*Indicate how much you agree with the following statements:*
P15_23	I try to follow a Mediterranean and traditional diet, avoiding prepared meals.
P15_45	I do more exercise for my health than for my look
P15_6	When it comes to food, I'm always looking for something new
P15_7	Every time I eat less meat and I focus on a more vegetarian diet
P15_8	I try to treat myself every day
P19	*Indicate how much do you agree with the following statements:*
P19_12	I prefer food produced locally or from our country
RELEVANCE	
P13	*Indicate how much you agree with the following statements:*
P13_3	When I deal with new products, the brand is important to me
P13_10	The taste of meals is more important than the ingredients
P13_11	Food packaging is important to me
P15	*Indicate how much you agree with the following statements:*
P15_1	My diet and that of my family is very important to me
P17	*Given the choice of food products, are the following factors important to you?*
P17_1	Quality
P17_23	Health care and food safety
P17_4	Origin in organic farming and livestock
P17_56	Produced locally or in the country
P18	*Indicate the importance of each of the following factors for you:*
P18_1234	Respect for the environment, recycling, preserve natural resources and sustainable production

Table S2. Characteristics of consumption habitude.

	Global[1] n=401	Cluster 1 n=276	Cluster 2 n=125
Consumption frequency			
Pork meat			
Once or more weekly	69.58	73.91	60.00
Once or more monthly	21.20	18.12	28.00
Occasionally	7.98	6.52	11.20
Never	1.25	1.45	0.80
Iberian pork meat			
Once or more weekly	38.25	41.82	30.40
Once or more monthly	39.50	41.09	36.00
Occasionally	20.50	16.73^{B}	28.80^{A}
Never	1.75	0.36	4.80
Pork products			
Once or more weekly	75.31	75.74	74.40
Once or more monthly	16.12	13.60	21.60
Occasionally	7.05	8.82^{A}	3.20^{B}
Never	1.51	1.84	0.80
Iberian pork products			
Once or more weekly	52.00	56.36	42.40
Once or more monthly	28.75	28.00	30.40
Occasionally	18.50	15.27	25.60
Never	0.75	0.36	1.60
Place of purchase			
Meat and meat products			
Butcher's shop	59.33	67.17^{a}	44.12^{b}
Supermarket butcher	53.00	53.03	52.94
Packaged meat	40.00	33.84^{B}	51.96^{A}
Others	5.02	4.57	5.88
Food			
Food market	46.63	55.07^{a}	28.00^{b}
Local shop	44.39	46.38	40.00
Local grocery shop	79.80	79.35	80.80
Agricultural Cooperative	10.72	10.87	10.40
Gourmet shop	10.97	11.96	8.80
Large grocery store	44.64	42.75	48.80

Different superscripts indicate significant differences between Clusters: A, B: P <0.01 and a, b: P<0.05. [1]Two consumers were not considered in the clusters due to missing values in some of the segmentation questions.

Figure S1. Dendogram of the cluster analysis.



Conclusiones

Conclusiones

1.- La optimización del uso de recursos naturales procedentes de la dehesa reduce los impactos ambientales del cambio climático, la acidificación, la eutrofización y la demanda de energía acumulada en la producción tradicional del cerdo Ibérico, aproximándose a sistemas productivos porcinos más respetuosos con el medio ambiente. Por otro lado, se produce un mayor impacto ambiental de ocupación de suelo debido al uso de grandes superficies para el aprovechamiento óptimo de los recursos naturales. La incorporación de emisiones derivadas del consumo de recursos naturales debe ser incluidas en el Análisis de Ciclo de Vida para evitar una subestimación de los impactos ambientales calculados (Capítulo primero).

2.- La tipificación de ganaderías tradicionales de cerdo Ibérico define dos grupos diferenciados en cuanto a aspectos técnicos, productivos y económicos. Un grupo de ganaderías se caracteriza por la producción de diferentes tipos de animales (lechones, marranos, primales o cebones) con un mayor nivel de intensificación, mientras que el otro grupo de ganaderías se caracteriza por maximizar la utilización de los recursos naturales de la dehesa a través de un sistema de ciclo cerrado. Las ganaderías orientadas hacia un sistema de ciclo cerrado son más sostenibles desde un punto de vista económico y ambiental (Capítulo segundo).

3.- Los sistemas de engorde del cerdo Ibérico en la dehesa muestran una gran diferenciación en aspectos técnicos y ambientales. La clasificación de las ganaderías de Ibérico según el tipo de engorde es posible a través de variables ambientales. El uso conjunto de los sistemas de montanera y cebo de campo se desmarca como una estrategia óptima para mejorar la sostenibilidad en la producción tradicional de cerdo ibérico. Mientras que el cebo en montanera optimiza el uso de los recursos naturales que ofrece la dehesa, siendo una producción ganadera más respetuosa con el medio ambiente, el cebo de campo permite realizar el engorde de los animales cuando la bellota no está disponible estacionalmente, resultando una producción porcina más rentable (Capítulo tercero).

4.- La evaluación de la ecoeficiencia de las ganaderías de cerdo Ibérico en la dehesa a través de una metodología combinada del Análisis de Ciclo de Vida y el Análisis Envolvente de Datos ha demostrado ser una herramienta muy valiosa para la comparación de parámetros ambientales, técnicos y económicos. Las ganaderías de cerdo Ibérico mostraron un alto nivel de ecoeficiencia, siendo mayor en las explotaciones con un manejo más tradicional. El perfil profesional del ganadero y la importancia del engorde en montanera influyen significativamente en el nivel de ecoeficiencia de las ganaderías de cerdo Ibérico en la dehesa (Capítulo cuarto).

5.- La gran mayoría de los consumidores españoles no conocen los criterios que debe cumplir la producción de cerdo ibérico y cuáles son las características de los diferentes productos ibéricos. Aun así, los consumidores independientemente de su nivel de conocimiento sobre la producción porcina Ibérica y sus características demográficas consideran los productos ibéricos de mayor calidad, más sabrosos, más sanos y producidos con mayores estándares de bienestar animal que los productos porcinos de razas blancas comerciales. De este modo, los consumidores consideran la raza el factor más importante a la hora de elegir un producto porcino y su sistema de producción el segundo factor más importante, mostrando preferencia por los sistemas productivos extensivos frente a los intensivos. El precio es el factor estudiado con menor importancia para los consumidores a la hora de elegir un producto porcino. Por todo ello, el etiquetado en los productos del cerdo Ibérico de producción tradicional tiene una gran importancia para poder llegar a un mayor número de consumidores (Capítulo quinto).

6.- La mayoría de los consumidores conocen la sostenibilidad, pero no son conscientes de la amplitud del concepto. Se diferenciaron ligeramente dos grupos de consumidores. Un grupo de consumidores respondió a más atributos relacionados con la sostenibilidad, y el otro grupo de consumidores presentó un concepto menos amplio de sostenibilidad. La educación y la información de los consumidores limitan la transformación de la actitud del consumidor en decisiones y prácticas de compra de alimentos más sostenibles. El marco de la producción del cerdo Ibérico todavía manifiesta un escaso conocimiento de los valores añadidos del sistema tradicional de producción en la dehesa que son los impulsores para su mayor sostenibilidad (Capítulo sexto).

Conclusions

1.- The greater use of natural resources from *dehesa* ecosystem reduces climate change, eutrophication, acidification and cumulative energy demand impacts in Iberian traditional pig production, which can reach values close to those obtained for more eco-friendly pig production systems. As a result, land occupation impact is increased due to the use of large surfaces to provide natural resources from the *dehesa*. The incorporation of emissions resulting from the consumption of natural resources should be included in the Life Cycle Assessment to avoid underestimation of the environmental impacts for systems in which natural resources are used (First chapter).

2.- The Iberian traditional pig farms typology defines two groups of farms framed on technical, productive and economical aspects. A farm group is characterised by the production of different types of pigs (piglets, growers, and fatteners) with a higher level of intensification. While the second farm group is characterised by an optimal use of natural resources in a farrow-to-finish. Iberian traditional farms oriented structurally towards farrow-to-finish system are more sustainable from an economic and environmental approach (Second chapter).

3.- Iberian pig fattening systems located in the *dehesa* ecosystem show a great differentiation in technical and environmental aspects. Classification of Iberian farms according to the type of fattening is possible through environmental variables in a more precise manner. The combined use of fattening *montanera* and *cebo de campo* is an optimal fattening strategy to improve the sustainability of the Iberian traditional pig production. While the fattening *montanera* optimises the use of the natural resources offered by the *dehesa*, being a more eco-friendly livestock production, the fattening *cebo de campo* permits the fattening phase to be carried out when acorns are not seasonally available, resulting in a more profitable pig production (Third chapter).

4.- The assessment of the eco-efficiency in Iberian traditional pig farms through a combined methodology of Life Cycle Analysis and Data Envelopment Analysis has proved to be a very valuable tool for the comparative assessment of environmental, technical and economical parameters. The Iberian pig farms showed a high level of eco-efficiency in the dehesa, being more eco-efficient those farms with traditional management. The professional profile of the farmer and the importance of fattening *montanera* influence the level of eco-efficiency of the Iberian pig farms in the *dehesa* (Fourth chapter).

5.- The great majority of consumers did not know which criteria need to be fulfilled by Iberian pig production and which are the characteristics of the different Iberian products. Even so, consumers independently on the geographic area studied, consider Iberian products of higher quality, tastier, healthier and produced with higher standards of animal welfare than pork products from white commercial breeds. Thus, consumers considered pig breed the most important attribute when choosing a pork product and its production system is the second most important factor, showing a preference for extensive over intensive systems. The price was the least important attribute for consumers. The labelling of the products from Iberian pigs that are traditionally produced is of great importance in order to reach a high number of consumers (Fifth chapter).

6.- Most consumers know about sustainability, but they are not aware of the ampleness of the concept. A group of consumers responded to more type of sustainability-related attributes, and another group of consumers presented a less expanded concept of sustainability. Consumers' education and information limit the transformation of consumer attitude in sustainable diet-purchase decisions and practice. The framework of the Iberian pig production still manifests a low knowledge of the traditional farm system attributes that are drivers to make it more sustainable (Sixth chapter).

Resumen

Resumen

El cerdo Ibérico ha estado vinculado tradicionalmente al agroecosistema de la dehesa mediante una producción extensiva. En las últimas décadas, la producción porcina Ibérica se ha transformado hacia un sistema más intensivo. La limitación de superficie de dehesa y la falta de rentabilidad de las explotaciones ganaderas han derivado en una sobreexplotación de este agroecosistema tan singular, amenazando el equilibrio existente entre la dehesa y la producción ganadera tradicional que se desarrolla. En la actualidad, la Unión Europea fomenta métodos de producción agrarios más sostenibles, los cuales se encuentran potenciados por una mayor concienciación de la sociedad hacia sistemas de producción más respetuosos con el medio ambiente y los animales. Dada la importancia del sector porcino Ibérico en nuestro país, resulta necesario la investigación de planes estratégicos en todo el circuito alimentario, desde la producción ganadera hasta los consumidores del producto final. Por ello, la búsqueda de mejoras desde un punto de vista ambiental, económico y social son primordiales para asegurar un futuro a largo plazo del sistema tradicional del cerdo Ibérico.

Con esta premisa, esta tesis doctoral se presenta como un compendio de publicaciones en las que se evalúa de manera multidisciplinar el sistema de producción del cerdo Ibérico con el fin de alcanzar una producción porcina más sostenible. A través de herramientas de evaluación sistémica ha sido posible evaluar desde diferentes enfoques la sostenibilidad del sistema productivo del cerdo Ibérico, con el fin de formular estrategias para conseguir un efecto ambiental y socioeconómico positivo en este sistema ganadero tradicional. El establecimiento de una tipología de sistemas de porcino Ibérico actuales ha permitido caracterizar y evaluar comparativamente su capacidad de continuidad en el agroecosistema de la dehesa. Para ello, se cuantificó y evaluó el impacto ambiental de la producción porcina Ibérica a través del Análisis de Ciclo de Vida. Posteriormente, mediante un proceso de integración de diferentes variables se analizaron las diferencias y similitudes existentes entre los sistemas de engorde existentes en la dehesa. Además, el Análisis Envolvente de Datos permitió evaluar el nivel de ecoeficiencia en las ganaderías porcinas. Todo ello ha permitido identificar los procesos y prácticas ganaderas que optimizan la producción porcina desde un punto de vista técnico y ambiental, fortaleciendo la adopción de prácticas ganaderas más sostenibles a la vez que más competitivas. Finalmente se abordaron las preferencias de los consumidores con respecto a los productos cárnicos de origen porcino y se analizó el comportamiento de compra respecto a alimentos sostenibles en España con el objetivo de adaptar la producción porcina Ibérica a las demandas del mercado actual.

Una producción porcina Ibérica más ligada a la tierra y con un manejo más tradicional, en el cual destaca un aprovechamiento óptimo de los recursos naturales disponibles en la dehesa, genera menos impactos ambientales y presenta una mayor ecoeficiencia. Las ganaderías de cerdo Ibérico orientadas hacia un sistema de ciclo cerrado son más sostenibles desde un punto de vista económico y ambiental. El uso combinado del engorde en montanera y cebo de campo constituye una estrategia adecuada para mejorar la sostenibilidad de la producción porcina debido a que optimiza la utilización de recursos naturales y aumenta la rentabilidad económica de las ganaderías. La gran mayoría de los consumidores no conocen el sistema productivo del cerdo Ibérico, así como prácticas de consumo más sostenibles, como un mayor grado de bienestar animal o sistemas de manejo extensivos, que son impulsores de una producción de cerdos Ibéricos más sostenible. Aun así, los consumidores muestran preferencia por los productos ibéricos con respecto a los productos porcinos procedentes de razas blancas comerciales.

Abstract

Iberian pig is linked to the *dehesa* ecosystem through livestock extensive production. In recent decades, Iberian pig production has been transformed towards a more intensive system. The limitation of *dehesa* hectares and the lack of profitability of Iberian pig farms have caused an overexploitation of the *dehesa* ecosystem. At present, European Union promotes a more sustainable agricultural production. Moreover, consumers increasingly prefer food from environmentally and animal-friendly production systems. Due to the importance of the Iberian pig sector in Spain, it is necessary to research strategic plans in the food supply chain from livestock production to consumers. Therefore, environmental, social and economic improvements in Iberian pig production are essential to ensure the long-term future of this traditional livestock.

This PhD thesis is presented as a compilation of papers where a multidisciplinary evaluation of Iberian traditional pig production is carried out in order to achieve a more sustainable pig production. The sustainability of the Iberian pig production system has been evaluated through different tools to elaborate strategies to achieve a positive environmental and socio-economic effect on this traditional livestock system. Establishing a structural typology for the Iberian pig farms has facilitated the characterisation and evaluation of their capacity for continuity in the *dehesa* ecosystem. In addition, the environmental assessment of the Iberian traditional pig production was carried out through Life Cycle Assessment. Afterwards, multivariate analysis techniques were used to analyse differences and similarities in technical and environmental variables among fattening types in the *dehesa* ecosystem. In addition, Data Envelopment Analysis allowed to evaluate the eco-efficiency in Iberian pig farms. All these tools have identified farming practices that optimise Iberian pig production from a technical and environmental approach, promoting the implementation of more sustainable and competitive farming practices. In further analysis, consumer preferences for pork products were studied together with consumption patterns regarding sustainable food in Spain with the aim of adapting Iberian pig production to current market demands.

Iberian pig production generates lower environmental impacts and presents a superior eco-efficiency by linking farm management to the *dehesa* ecosystem, showing an optimal use of natural resources. Iberian pig farms with farrow-to-finish orientation are more sustainable from an environmental and economic approach. The combined use of fattening *montanera* and *cebo de campo* is the optimal fattening strategy to improve the sustainability in Iberian traditional pig production by optimising the use of natural resources offered by the *dehesa* ecosystem and resulting in a more profitable pig production. The majority of consumers have a low level of knowledge of Iberian pig production, as well as more sustainable consumption practices. For instance, consumers have no knowledge about adding value to Iberian pig, as high welfare standards or an extensive farming, that are drivers for a more sustainable Iberian pig production. Even so, consumers show a preference for Iberian products over pork products from white pig breeds.

Anexos

Anexo I. Cuestionario realizado en las ganaderías participantes.

Anexo II. Cuestionario realizado en el estudio de consumidores.

Fecha encuesta:

SECCIÓN A: DATOS GENERALES

Nombre de la explotación: ____

Encuestado Nombre

☐ Propietario ____

☐ Gerente ____

☐ Porquero ____

Dirección finca: Coordenadas:

Municipio: Provincia:

Teléfono de contacto: Correo electrónico:

____________________ _______________________________________

SECCIÓN B: INVENTARIO Y MANEJO GENERAL DE LA FINCA

0. USO DEL TERRENO

Nº Hectáreas de la Finca___________

Hectáreas en propiedad___________

Hectáreas arrendadas ____________ (€/ha)___________

Hectáreas uso ganadero___________

Hectáreas uso agrícola____________

1. INVENTARIO

1.1. ¿Cuántos **CERDOS** de las siguientes etapas hubo el último año en la finca?

I.-Madres_____________ III.- Renuevo Hembras__________

II.-Verracos____________ IV.- Renuevo Machos_____________

V.-Cría (lechones) ___________ VI.-Recría (marranos y primales) ______________

VII.-Cebo: ¿compra animales para cebo? _____ ¿qué tipo de cebo realiza? ¿Montanera?_________ ¿Campo?____________ ¿Intensivo?__________

1.2. ¿Qué **INSTALACIONES** se pueden encontrar en la finca?

Tipo de instalación	Superficie (m^2)	Tipo de suelo (tierra, cemento, slat)	Valor en su día de compra o construcción (€)	Edad del bien (años)	¿Qué tipo de animales hacen uso de la instalación?

Plazas de campings, si utiliza___________

Nota: nave, corral, almacén, cercado, vivienda, puntos de agua, mangadas, embarcadero, lazareto, fosa purines.

Otros aspectos instalaciones porcino:

a) Ventilación: ☐Natural ☐Forzada ☐Mixta

b) Refrigeración en gestación: ☐Sí ☐No

c) ¿Qué tipo de material manipulable o de enriquecimiento dispone en los campings o naves para los animales?
☐Paja ☐Pelota ☐Cuerda ☐Palos ☐Ninguno

Otros aspectos instalaciones en general:

a) Uso de luz eléctrica ☐Red pública ☐Autogenerador ☐No utilizo

b) Dispone de agua: ☐Corriente ☐ Pozo ☐Río-manantial ☐Otro ___________

Servicio	Actividad o lugar de uso	Porcentaje	Actividad o lugar de uso	Porcentaje
Electricidad				
Agua				

c) Distancia en km desde la carretera hasta la vivienda: _____

d) Tipo de acceso: ☐ Camino en malas condiciones
☐ Camino en buenas condiciones
☐ Asfalto

1.3 ¿Qué **MAQUINARIA** se puede encontrar en la finca?

Tipo de maquinaria	**Número**	**Valor de compra en su día (€)**	**Edad del bien (años)**

Nota: coche, tractor, remolque, sembradora, sembradora, abonadora, grada de discos, generador, bombas, molino, silo, cadena alimentación, báscula,…

2. MANEJO GENERAL DE LA FINCA

2.1 MANEJO **REPRODUCTIVO**

2.1.1 ¿Qué tipo de cubrición se realiza en la finca?

a) Inseminación artificial b) Monta natural c) Ambas

2.1.2 ¿Cuántas cubriciones o inseminaciones realiza al año?_______¿y parideras?________

2.1.3 Señale en qué momento realiza montas o inseminaciones

Montas	Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Diciembre

2.1.4 Si realiza I.A. pase a la pregunta 2.1.5.
¿Cuántos lotes por cubrición realiza? ____
¿Cuántas hembras entran a ser cubiertos en cada lote?_________
¿Cuántos machos se introducen en cada lote? ____ ¿Cuánto tiempo deja el macho con las hembras?_____días

2.1.5 ¿De qué raza o razas son los machos que utiliza? ☐Ibérico ☐Duroc ☐IbéricoXDuroc

2.1.6 ¿Realiza ecografías para diagnóstico de gestación? ☐Sí ☐No

2.1.7 Del total de hembras que se cubren ¿cuántas paren?___________

2.1.8 En promedio ¿Cuántos lechones en total nacen por hembra?_________¿Cuántos nacen vivos? _______

2.1.9 En promedio ¿Cuántos lechones desteta por hembra?________ ¿Edad destete? _______días ¿Peso?_____ kg

2.1.10 Edad primera cubrición cerda ______meses

2.1.11 Vida reproductiva media cerda_______años

2.1.12 ¿Realiza alguna estrategia para inducción al celo? ☐Sí ☐No
Si su respuesta es **SÍ**, ¿cuál y de qué modo?

	Indicar (tiempo, kg suplementación/días)
Efecto macho	
Flushing	
Tratamiento hormonal	
Otros	

¿Suplementa a reproductoras? ☐Sí ☐No
Si su respuesta es **SÍ**, ¿cuándo y de qué modo?

	Kg/día	Nº días	€/kg
Antes del parto			
Post-parto			
Hasta el destete			

¿Les proporciona suplemento mineral (sal)? ☐Sí (especificar producto y cantidad: _________________)
☐ No

2.1.13 **Reposición y desvieje**

a) Estrategia de reposición (Califique de 1 a 5 los criterios de selección, donde 1 es algo que le importa mucho y 5 tiene poca importancia)

Criterio selección	Carácter maternal	Conformación	Prolificidad	Capa	Genética
Valor					

b) ¿Qué procedencia tiene el renuevo de la explotación? (Marcar con un **X**) ¿Qué % de reposición se realiza?

	Propia	Ajena	Reposición media (%)	Coste (€/animal)
Madres				
Verracos				

c) Estrategia de desvieje o desecho en los últimos 12 meses (Califique de 1 a 5 los criterios de desecho, donde 1 es algo que le importa mucho y 5 tiene poca importancia)

Criterios desecho	Edad	Problemas de lactancia	Problemas reproductivos	Problemas sanitarios	Otro________
Valor					

2.2 ALIMENTACIÓN

Cuadro etapas y alimentación ofrecida

Etapa	Duración etapa	Peso		Alimento ofrecido a cada animal					
		Inicio	Final						
	Días o meses	Kg o @		Pienso		Pasto o Pradera	Bellota	Paja	Otros (subproductos)
				Kg/día	€/kg				
Madres vacías									
Madres en cubrición									
Madres gestantes									
Madres lactación									
Verracos parados									
Verracos en cubrición									
Lechones									
Cría									
Recría									
Montanera									
Cebo campo									
Cebo corral									
Renuevo hembras									
Renuevo machos									

*Muy importante obtener la cantidad de pienso que se ofrece al día en cada etapa que aplique

2.2.1 En total ¿Cuánto pienso se compró el último año? ____________kg totales
¿Cuál es el origen del pienso? ______________________

2.2.2 Además de pienso ¿Qué otro tipo de alimento compró? (paja, ensilado,…) ______________________________
¿Cuánto? _______en Tn o kg_______

2.2.3 MONTANERA

a) ¿Realiza montanera? ☐Sí ☐No (Si su respuesta es **NO** pasar a la pregunta **2.2.4**)

b) Tipo de pastoreo:

- En cercas (rotacional) ☐
- En un único cercado ☐
- Conducido o guiado ☐
- Otros ☐

c) Lugar de pastoreo:

Pastos naturales ☐
Sembrado cereal ☐
Praderas cultivadas (leguminosas) ☐
Otros ☐

d) Fechas de montanera

	INICIO	FINAL
Fechas		

e) ¿Con qué edad entran los cerdos a montanera? ___________meses
f) ¿Cuántas hectáreas destina a montanera? _______ha
g) ¿En promedio que densidad hay de encinas en la finca? (encinas/ha) _________ ☐NS
h) ¿Producción de bellota? (kg/encina) _________ ☐NS

2.2.4 MANEJO ALIMENTICIO

a) ¿Tienen los animales acceso a agua 24 horas al día? ☐Sí ☐ No
b) ¿Tienen los animales acceso a comida 24 horas al día? ☐Sí ☐ No
c) Si ha respondido NO, ¿Cuántas veces al día disponen los animales de comida? _______
d) ¿Las dietas las propone un nutrólogo profesional? ☐Sí ☐ NO
e) ¿Si lo conoce, cuál es el caudal (litros por minuto) de los bebederos?_______
f) ¿Cómo se alimenta a las cerdas gestantes?
☐Como grupo (i.e. dejando una sola pila de comida para todo el grupo)
☐Individualmente a través de ESF (comederos)
☐Otros..............................
g) A las cerdas gestantes, ¿se les raciona la comida de modo individualizado según condición corporal? ☐Sí ☐ No
h) ¿Cómo se proporciona el aporte de fibra que indica la legislación para las cerdas gestantes?
☐ Con paja en el comedero
☐ En la propia dieta
☐ No está contemplado
i) ¿Dispone de un sistema de entrenamiento previo de las cerdas al sistema de alimentación?
☐ No
☐ Sí

2.3 OTRAS ACTIVIDADES EN LA FINCA (AGRICULTURA Y GANADERÍA)

2.3.1 ¿Además de la cría de cerdos realiza otras actividades agrícolas dentro de la finca?

☐ Sí (continua)
☐ No (pasar a la pregunta **2.3.8**)

2.3.2 ¿Qué otras actividades realiza dentro de la finca?

☐ Siembra de cereales (trigo, etc) ha destinadas_______________ rendimiento (Ton/ha)__________________
☐ Siembra de forraje ha destinadas ______rendimiento (Ton/ha)______camiones, naves_______________
☐ Otro tipo de cultivo___________________ ha destinadas_________ rendimiento (Ton/ha)________________
☐ Área forestal ha destinadas________________________
☐ Coto de caza
☐ Recreativos (casa rural, visitas guiadas,…)

2.3.3 ¿Fertiliza la zona agrícola? ☐Sí ☐No

¿Con qué? y ¿cuánto por hectárea?

☐Sintético______________

☐Orgánico (excrementos, compost) _______________

☐Otro__________________

Gastos fertilizantes al año _______ €

2.3.4 Uso del producto agrario obtenido en los cultivos (señale las opciones necesarias):

Consumo animal de su propia granja ☐ Sí (especifique especie: ____________) ☐ No

Venta ☐ Sí (dónde__________) ☐ No

2.3.5 Transformación del producto ☐ Sí (tipo de producto___________) ☐ No

2.3.6 Conservación del forraje: ☐Henificado ☐ Ensilado

2.3.7 ¿Se comparten los pastos con otras especies domésticas en los ciclos de rotación? ☐ Sí ☐ No

¿con cuáles? ______________________________ ¿cuántas hectáreas se comparten? _______________

2.3.8 ¿Realizó otras actividades ganaderas en la finca? ☐ Si (continuar) ☐ No (pasar a la pregunta **2.3.10**)

2.3.9 ¿Qué otras actividades pecuarias realiza?

☐ **Bovinos Inventario: Vacas:_________ Toros:_________ Renuevo:________________**
Animales vendidos _________________ ¿tipo?________________Precio medio_______€

☐ **Ovinos Inventario Ovejas:_________ Carneros:_________ Renuevo:_______________**
Animales vendidos________________¿tipo?_______________ Precio medio_________€

☐ **Otra especie_______________Inventario: Hembras: _________Machos:____________**
Animales vendidos________________¿tipo?_______________ Precio medio_________€

2.3.10 ¿Qué % de ingresos supone la actividad porcina sobre el resto de actividades de la explotación?_____%

2.3.11 ¿Qué % de ingresos supone cada una de las demás actividades? Agrícolas ______%

Ganaderas_____%

2.4 ASPECTOS SANITARIOS

2.4.1 **Tratamientos sanitarios**

a) Calificación sanitaria:________________

b) ¿Qué enfermedades se presentan a lo largo del año?

c) ¿Contra qué enfermedades vacuna?

d) ¿Qué pauta vacunal realiza?

e) ¿Desparasita a los cerdos de su explotación? ☐Sí ☐ No
Si su respuesta es **SI**, ¿Con qué frecuencia y método desparasita a los cerdos? _______________________

f) ¿Qué otros tratamientos utiliza habitualmente? Especifique el nombre:

☐complejos vitamínicos-minerales ______________________________

☐antibióticos____

☐analgésicos ____

☐otros ____

g) En los tres últimos meses, ¿cuántos animales han recibido tratamiento antibiótico? _______

h) ¿Aísla a los animales enfermos de algún modo? ☐ Sí ☐ No

i) ¿El personal que trabaja con el ganado ha recibido formación en selección y administración de medicamentos veterinarios? ☐Sí ☐ No

j) Coste de medicación en el último año (hacer constar si el periodo es diferente):_________________

2.4.2 **Mortalidad y sacrificio**

Bajas en el último año

Etapa	**Nº de animales muertos**	**Causa principal de la muerte**
Reproductoras		
Verracos		
Lechones		
Cría		
Recría		
Cebones en montanera		
Cebones en cebo campo		
Cebones en cebo corral		
Renuevo hembras		
Renuevo machos		

a) ¿Cuál es el porcentaje de eutanasias?_______%
b) ¿Cómo se practica la eutanasia en los animales?
☐ Pistola bala cautiva
☐ Fármacos
☐ Otros _______________________________
c) De los cerdos sacrificados en los últimos 3 meses ¿Cuántas canales han sido rechazadas?________ ☐NS
d) Por favor, anote los principales motivos de rechazo
1.________________________
2.________________________
3.________________________

2.5 MANEJO ANIMAL

2.5.1 Lechones

a) Cuando destetan, ¿los lechones se mezclan en corrales? ☐Sí ☐ No
En caso de no formar grupos mezclados, ¿qué hacen con los lechones? ___________________________

b) En caso de que sí, ¿de cuánto son los grupos?
☐menos de 30 lechones ☐ de 30-50 lechones ☐ más de 50 lechones

c) ¿Establece los grupos de lechones separando por sexo o por pesos?
☐por sexo ☐ por pesos ☐ ni por sexo, ni por pesos

d) ¿Cuánto tiempo permanecen normalmente los lechones en esos grupos?
☐menos de 1 mes ☐ de 1 a 3 meses ☐ más de 3 meses

e) ¿Se cortan las colas de los lechones de forma rutinaria (manejo intensivo)?
☐ No
☐ Sí. *En este caso, ¿puede explicar por qué, cuándo y cómo se realiza?*

¿Por qué? ___________________________
¿Cuándo? ___________________________
¿Cómo?

f) ¿Se cortan los dientes de los lechones de forma rutinaria (manejo intensivo)?
☐ No
☐ Sí. *En este caso, ¿puede explicar por qué, cuándo y cómo se realiza?*

¿Por qué? ___________________________
¿Cuándo? ___________________________
¿Cómo?

g) Anillado
☐ No
☐ Sí. *En este caso, ¿puede explicar por qué, cuándo y cómo se realiza?*

¿Por qué? ___________________________
¿Cuándo? ___________________________
¿Cómo?

h) ¿Aplica algún Código de Buenas Prácticas específico para mejorar el bienestar animal al que no esté obligado por la normativa vigente?
☐ No
☐ Sí *cuáles:*

____
____

j) ¿Su personal está formado en el cuidado de animales? ☐Sí ☐No

k) ¿Qué utiliza para mover a los animales?
☐Plafón de madera ☐ Pica eléctrica ☐ Perros ☐ Palo ☐ Otro método ___________________

l) Castración

Sexo	Edad castración	Método	Persona que lo realiza	Tiempo empleado por animal	Anest.*	Analg. *	Antib.*	%Infecc.	Mortalidad
Machos									
Hembras									

*Durante el procedimiento/ después/no utiliza

m) ¿Conoce la inmunocastración? ☐ Sí ☐ No

n) ¿La ha probado? ☐ Sí ☐ No

o) Opinión y razones en caso de no utilizarla____

2.5.2 Alojamientos

Etapas	Tipo y cantidad													Días de uso	Superficie destinada		
	Jaula/slat	Jaula/hormigón	Jaula/tierra	Camping individual	Camping en grupo	Corral cemento	Corral tierra	Corral hormigón/tierra	Corral slat	Corral slat/cemento	Cercado sin arbolado	Dehesa	Otro		m^2, ha, etc	Individual	En grupo
Madres vacías																	
Madres en cubrición																	
Madres gestantes																	
Madres lactación																	
Verracos parados																	
Verracos en cubrición																	
Lechones																	
Cría																	
Recría																	
Montanera																	
Cebo campo																	
Cebo corral																	
Renuevo hembras																	
Renuevo machos																	

Tipo de instalación utilizada en la etapa según corresponda, indicar cantidad, indicar el tiempo que se ocupa, la superficie y marcar con X si esa superficie es para un animal o para el grupo

2.6 MANEJO DE DESECHOS

2.6.1 Manejo de purines

Alojamiento	Recolección					Almacenamiento							Distribución					
	Pala y carretilla	Tractor	Golpe de agua	Cañería	¿Cada cuanto?	Fosa	Lago	Estercolero	Compost	Biodigestor	Campo	¿Cuánto tiempo?	Campo	Cultivo propio	Dehesa	Campo o cultivo ajeno	Recolección pagada	Otro
Jaula/slat																		
Jaula/hormigón																		
Jaula/tierra																		
Camping individual																		
Camping grupo																		
Corral de hormigón																		
Corral de tierra																		
Corral hormigón/tierra																		
Corral slat																		
Corral slat/hormigón																		
Cercado sin arbolado																		
Dehesa																		
Otro																		

Según el tipo de instalación marcar con X el método que utiliza e indicar tiempo de permanencia de los purines en esa instalación

2.6.2 ¿Echa algún tipo de cama a los animales? Sí☐ (Continuar) No ☐ (pasar a la pregunta **2.7**)

2.6.3 ¿Qué material?

☐ Serrín ¿Cuánto? ________

☐ Tierra ¿Cuánto? ________

☐ Paja ¿Cuánto? ________

☐ Otra_________ ¿Cuánto? ________

2.6.4 ¿Cada cuánto o cuando retira la cama? ____________________

2.7 BIOSEGURIDAD

a) ¿Se dispone de vallado perimetral? ☐ Sí ☐ No

b) ¿Existe vado sanitario? ☐ Sí ☐ No

c) ¿Se utiliza vestimenta y calzado especial para entrar a las naves o recintos? ☐ Sí ☐ No

d) ¿Hay control sobre las personas que entran y salen de la explotación? ☐ Sí ☐ No

e) ¿Existe contacto de los animales con animales silvestres? ☐ Sí ☐ No

f) ¿Qué especies salvajes pueden encontrarse en la zona?

☐ Jabalíes ☐ Aves

☐ Ciervos ☐ Conejos o liebres

☐ Zorros ☐ Roedores

g) ¿Entran o hay animales de compañía en la finca?
☐ Perros ☐ Gatos ☐ Perros y gatos ☐ Ninguno

h) ¿A qué distancia se encuentra su explotación de otra finca de cerdos? ___________

i) ¿Qué se hace con los animales muertos?

☐ Servicio recogida el mismo día ☐ Se acumulan hasta fecha o cantidad (servicio de recogida)

☐ Se dejan a los buitres (muladar) ☐ Se incineran

☐ Se los comen perros, gatos,... ☐ Se entierran

☐ Otro_______________

j) ¿Lava y desinfecta las instalaciones con regularidad? ☐ Sí ☐ No

k) ¿Con qué producto lava o desinfecta? __________________

l) El ganado procedente de otra explotación ¿dónde lo recibe?

☐ En corrales separados para observación o cuarentena

☐ Con el resto de animales de la explotación

m) Los grupos de animales se mezclan:

☐ Al destete o a la entrada

☐ Tras este período

SECCIÓN C: ESTRUCTURACIÓN DE LA EXPLOTACIÓN

3. ASPECTOS SOCIALES y CAPITAL HUMANO

3.1 CUESTIONES PERSONALES

a) Respecto al titular de la explotación:

Edad	Nº hijos	Nº personas que dependen de la explotación	Nº años dedicado a la actividad

ESTADO CIVIL		FORMACIÓN	
Casado	☐	Primarios	☐
Viudo	☐	Bachiller o FP	☐
Soltero	☐	Universitarios	☐
Divorciado	☐	Sin estudios	☐

b) ¿Por qué es ganadero? (Puede seleccionar más de una opción)
☐Heredé el negocio
☐Tradición familiar
☐Afición a los cerdos
☐No tenía otra opción
☐Creía/Creo que es una buena inversión o negocio
☐Otra____________________

c) Si no fuera ganadero, ¿qué haría?
☐ Tendría un negocio propio
☐Otro oficio en ganadería o agricultura
☐ Trabajar en el sector salud
☐ Trabajar en el sector público
☐ Trabajar en el sector privado (empresa)
☐ Otra_________________

d) ¿Cuáles son sus intereses personales como propietario de la finca? (Puede seleccionar más de una opción)

☐Sustento personal y familiar
☐Incrementar ingresos
☐Adquirir un bien (casa, coche…)
☐Educar a mis hijos en el campo
☐Retirarme y viajar por el mundo
☐Mantener la tradición familiar
☐Otro ___________________

e) ¿Cuáles son sus objetivos en la producción de cerdo? (Puede seleccionar más de una opción)
☐Exportar mi producto
☐ Ser el mejor de la región
☐Ser el mejor de España
☐ Mantener la tradición
☐Hacer crecer el negocio
☐Otro__________________

f) ¿Tiene intención de continuar en este negocio?
☐No
☐Sí, pero menos de 5 años
☐Sí, más de 5 de años

g) En el futuro, cuando deje la actividad:

¿Cree que sus hijos seguirán con el porcino?	☐Sí	☐No
¿Venderá los animales a un familiar?	☐Sí	☐No

Otra:____

h) ¿La ganadería es su actividad principal? ☐Sí ☐ No. Indicar cuál (sector____________)

i) Principales problemas que encuentra:

Grado de importancia	Poco			Mucho	
	1	2	3	4	5
1. Precio de la carne					
2. Alto Precio del pienso					
3. Disminución subvenciones					
4. Problemas con la administración					
5. Escasa superficie para montanera					
6. Hay sucesores en la explotación					
7. Problemas ambientales					
8. Pocos compradores de carne					
9. Exigencias sanitarias a la explotación					
10. Saneamientos					
11. Otros					

3.2 DATOS **ESTRUCTURALES**

a) ¿Cuál es el año de construcción de su explotación?

b) ¿Cuál es la orientación zootécnica de su explotación?

☐ Selección
☐ Producción de primales
☐ Recría de reproductores
☐ Producción
☐ Ciclo cerrado (cría, cebo y montanera)
☐ Producción de lechones
☐ Tipo mixto (lechones y adultos)
☐ Transición de lechones
☐ Engorde de primales
☐ Cebo (☐Montanera ☐Campo ☐Intensivo)

c) ¿Cuál es la capacidad productiva actual de su explotación?

☐ Grupo primero: explotaciones con capacidad de hasta 120 UGM
☐ Grupo segundo: explotaciones con una capacidad comprendida entre 121 UGM y hasta 360 UGM
☐ Grupo tercero: explotaciones con una capacidad comprendida entre 361 UGM y hasta 864 UGM
☐ NS

d) ¿Cuál fue la fecha de inicio de la adaptación a la normativa de bienestar animal? ☐NS

/ /

e) ¿La adaptación a esta normativa, supuso algún cambio en el censo o la orientación productiva de su explotación?

☐No
☐Sí *(en este caso elegir una de las siguientes opciones)*

☐ Cambiar de sistema de ciclo cerrado a producción de lechones
☐ Reducción del censo de reproductoras en la explotación
☐ Ampliación del censo de reproductoras en la explotación
☐ Otro. *Especificar:*

3.3 MANO DE OBRA

a) ¿Cómo selecciona a los trabajadores de la empresa?
☐ Valoración de la experiencia y conocimientos
☐ Recomendación de colegas del sector
☐ Contrato a familiares o amigos
☐ Otra ___________________________

b) Datos del personal (cuántos trabajadores contratados tiene)

Sexo	Edad	Antigüedad	Relación (propietario, socio, familiar o ajeno)	Nivel de estudio	Nacionalidad	Recidencia (finca o pueblo)	Salario	Jornada	Horario	Dias libres	Regimen laboral (SS agraria, general, autónomo)	Regimen fiscal (modulos, estimacion directa, sociedad limitada comunidad bienes)	Trabajadores eventuales

Nº trabajadores eventuales________ Nº jornales/año_______

c) ¿Cómo sabe que los trabajadores hacen bien su trabajo?
☐ Los califica el supervisor o encargado
☐ Marcando objetivos
☐ Valorando la producción final
☐ No los evalúo
☐ Otra_________________

d) ¿Reconoce o recompensa el trabajo de los mismos? ☐Sí ☐ No

e) ¿Cómo se lo recompensa?
☐ Incentivo económico
☐ Obsequio
☐ Reconocimiento simbólico (semanal, mensual o anual)
☐ Verbalmente
☐ No les recompenso de ninguna forma
☐ Otra ___________________________________

f) ¿Qué tipo de acciones de capacitación realizan sus empleados?

Personal	**Tipo** (Jornadas, formativos, conferencias u otras)	**Frecuencia**	**Temática** (Sanidad, producción, bienestar animal o riesgos laborales)

g) ¿Qué % de la jornada laboral dedica la mano de obra a la actividad porcina?________%

4. GESTIÓN DE LA EXPLOTACIÓN

a) Grado de asociacionismo

☐AECERIBER
☐RAZA (indique: ___________)
☐ADS
☐ORGANIZACIÓN AGRICULTORES/UPA (indique: __________)
☐COOPERATIVAS
☐Otras (indique:_______________)

b) ¿Se registra periódicamente información en la empresa? ☐Sí ☐No

c) ¿Qué información se registra? *(Puede seleccionar más de una opción)*

☐ Contable y financiera
☐ Entradas y salidas de animales
☐ Inseminaciones y/o cubriciones
☐ Fechas de partos y camadas
☐ Bajas y motivos
☐ Pesos
☐ Ganancias diarias de peso
☐ Consumo de alimento
☐ Fechas de vacunación
☐ Fechas de desparasitación
☐ Enfermedades y tratamientos realizados

d) ¿Para qué se utilizan esos registros? *(Puede seleccionar más de una opción)*

☐ Como un histórico
☐ Referencia
☐ Evaluar cambios realizados en la operación de la finca
☐ Evaluar el desempeño de los trabajadores
☐ Requisito veterinario o de asociación
☐ Llevar un control de la finca
☐ Otra_________________________

e) Asesoramiento de la empresa:

Asesor	Tipo (reproductivo/técnico/contable/ otro)	Cantidad de visitas al año	Condiciones
Veterinario			
Otro profesional:________________			
Otro experto:________________			

f) ¿Qué fuentes de información consulta regularmente? (Puede seleccionar más de una opción)

☐ Boletines
☐ Revistas
☐ Folletos
☐ Asesoramiento técnico
☐ Reuniones ganaderas
☐ Congresos técnicos
☐ Internet
☐ Recomendaciones de familiares y/o amigos
☐ Otro_____________________________

g) ¿Para qué utiliza la información consultada regularmente? (Puede seleccionar más de una opción)
- ☐ Información y tratamiento de enfermedades
- ☐ Novedades en producción
- ☐ Comparar con lo que estoy haciendo
- ☐ Corregir lo que estoy haciendo
- ☐ Ahorrar dinero
- ☐ Evitar la contratación de servicios técnicos
- ☐ Cumplir con la normativa vigente
- ☐ Otro: ____________________________

h) ¿Qué acciones de mejora tiene en marcha en la empresa?
- ☐ Mejoramiento genético
- ☐ Transición a modelo ecológico
- ☐ Formación del personal
- ☐ Mejoramiento de las instalaciones
- ☐ Cambio de alimentación
- ☐ Ampliación de la explotación
- ☐ Transición a modelo intensivo
- ☐ Ninguno

5. ASPECTOS ECONÓMICOS Y COMERCIALIZACIÓN

5.1 COMERCIALIZACIÓN, VENTA E INGRESOS

Venta de animales

Tipo de animal	Cantidad	Peso medio venta	Edad media venta	Precio de venta unidad	Forma de venta*
Lechones					
Marranos					
Primales					
Gordos montanera					
Gordos cebo de campo					
Gordos cebo de corral					
Desechos					
Hembras para vida					
Machos para vida					
Otros (___________)					

***Industrial, gran superficie, carnicero, tratante, cooperativa, venta directa, otras**

a) ¿Los productos de sus animales pertenecen a alguna D.O.P? ☐ Sí, ¿a cuál?_________________ ☐ No

b) ¿Los productos de sus animales cumplen la Norma del Ibérico? ☐ Sí ☐ No

Matanza

Proceso	Tipo de matadero (propio, municipal o privado)	Distancia en Km	Coste / animal
Matanza			
Despiece			
Secadero			

Venta de productos agrícolas

	€/año	Kg	€/kg
Cereales			
Leguminosas			
Paja o Heno			
Subproductos cosecha			
Otros			

Ventas subproductos origen animal

	€/año	kg	€/kg
Estiércol			
Purines			
Otros			

Subvenciones a la explotación

	€/año	Nº animales	€/animal
PAC			
Raza autóctona ó peligro extinción			
Ayuda extensificación (pastos)			
Ganadería ecológica			
Retirada de cadáveres			
Otras			

5.2 GASTOS

Compra de animales

Tipo de animal	Cantidad	Precio	Origen	Distancia	Tiempo traslado	Medio transporte	Muertos
Hembra reproductora							
Macho reproductor							
Lechones							
Recría (marrano, primal)							
Otros (___________)							

Suplementación animal y adquisición materias primas (uso en agricultura)

Alimento o materia prima*	**Origen**			**Cantidad total (kg)**	**Precio (€/kg)**
	Propio	Compra	Procedencia		

*Pienso, subproductos, cereales, semillas, paja, heno, otros

Servicios externos	€/ año	€/ animal
Administración		
Veterinario		
Asesor Fiscal		
Seguros		
Inspectora Norma		
D.O.P.		
AECERIBER		
Recogida de purines		
Otros		

Suministros	€/mes
Combustibles	
Electricidad	
Agua	
Teléfono	
Medicamentos	
Otros	

Reparaciones y conservación (€/año) __________
Arrendamientos tierra (€/año) __________
Arrendamientos instalaciones (€/año) __________
Arrendamientos maquinaria (€/año) __________

Gastos financieros

PRODUCTO FINANCIERO	Préstamo	Póliza	Hipoteca
Total endeudamiento (€)			
Tipo de interés (%)			
Pago anual (€/año)			

Tributos	€/año
IBI- Contribución	
IRPF o ISS	

SECCIÓN D: OBSERVACIONES DE LA EXPLOTACIÓN

CUESTIONARIO

Fecha:____________________ **Consumidor Nº:________**

Bienestar animal y cerdo ibérico

1. Habitualmente, ¿cuál es la **frecuencia de consumo** de los siguientes alimentos?

	Más de 1 vez por semana	1 vez por semana	1 vez cada 2 semanas	1 vez al mes	De manera ocasional	Nunca
Carne fresca de cerdo						
Carne fresca de cerdo ibérico						
Productos elaborados de porcino						
Productos elaborados de porcino ibérico						

2. Indique si está de acuerdo con las siguientes afirmaciones: **El criterio cerdo ibérico significa…**

	Sí	No	No sé
… que los cerdos son de raza ibérica pura o ibérico 100%			
… que parte de la crianza de los cerdos ha sido en campo en régimen de libertad			
… que los cerdos han sido alimentados con bellota			

3. Indique si está de acuerdo con las siguientes afirmaciones: **La categoría…**

	Sí	No	No sé
… de bellota significa que el cerdo se ha alimentado con bellotas en la última fase de cebo			
…. de cebo de campo significa que el cerdo se ha alimentado con pienso en régimen de libertad			
…. de cebo significa que el cerdo se ha alimentado con pienso en régimen de confinamiento			

4. ¿Conoce la existencia de una norma de calidad que regula la obtención de carne y productos porcinos ibéricos basada en la pureza racial y en la alimentación?

☐ Sí ☐ No ☐No sé

5. ¿Conoce la existencia de una norma que protege la salud y el bienestar animal de los cerdos en la granja y en el transporte?

☐ Sí ☐ No ☐No sé

6. Indique su nivel de acuerdo con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo				Muy de acuerdo
	1	2	3	4	5
Se debería incrementar las exigencias actuales sobre protección y bienestar animal de las granjas españolas					
El cerdo ibérico es criado en buenas condiciones de bienestar					
La carne y los productos del cerdo ibérico son de alta calidad					
La carne y los productos del cerdo ibérico son muy sabrosos					
La carne y los productos del cerdo ibérico son saludables					
El cerdo ibérico es criado en mejores condiciones de bienestar que el cerdo blanco					
La carne y los productos del cerdo ibérico son de más calidad que los del cerdo blanco					
La carne y los productos del cerdo ibérico tienen mejor sabor que los del cerdo blanco					
La carne y los productos del cerdo ibérico son más saludables que los del cerdo blanco					
Creo que la carne y los productos ibéricos son demasiado caros					

7. Indique su nivel de acuerdo con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

Cuando compro carne o productos cárnicos porcinos……

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
… el etiquetado es importante para mí					
… el criterio "de bellota" es importante para mí					
… el criterio "ibérico" es importante para mí					
… la denominación de origen es importante para mí					
… es importante para mí que los animales hayan sido criados en régimen de libertad					
… es importante para mí que los animales hayan sido criados en condiciones naturales					
... si son de ibéricos, la pureza racial es importante para mí					
… si son de ibéricos, la alimentación que han recibido es importante para mí					

8. **Afectaría negativamente a mi elección** de compra si supiera que… (1 muy poco o muy en desacuerdo, 5 mucho o muy de acuerdo):

	Muy poco 1	2	3	4	Mucho 5
Los cerdos han sido criados en régimen de confinamiento en granjas					
A los cerdos le han cortado la cola					
A los cerdos le han recortado los colmillos					
A los cerdos le han castrado quirúrgicamente					
A las cerdas se mantienen en jaulas					

9. **Estaría dispuesto a pagar más** por la carne y productos cárnicos ibéricos de cerdos que… (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
... han sido certificados como procedentes de granjas con condiciones de bienestar por encima de las actualmente exigidas en normativa					
… han sido certificados como procedentes de granjas ecológicas					
… han sido certificados como libres de organismos genéticamente modificados					
… han sido producidos bajo Denominación de Origen					
... han sido criados en régimen de libertad					
… han sido criados en condiciones naturales					
… han sido transportados al matadero sin lastimarse					

9b. **Afectaría negativamente a mi elección** de compra si supiera que… (1 muy poco o muy en desacuerdo, 5 mucho o muy de acuerdo):

	Muy poco 1	2	3	4	Mucho 5
Los cerdos han sido criados dentro de edificios cerrados sin acceso al exterior					
A los cerdos le han cortado la cola para evitar que se la muerdan en caso de estados de estrés					
A los cerdos le han recortado los colmillos para evitar lesiones en los pezones de las madres durante el amamantamiento					
A los cerdos le han castrado quirúrgicamente para evitar el olor sexual de la carne (olor desagradable)					
A las cerdas se alojan en jaulas durante la maternidad					

Sostenibilidad

10. ¿Alguna vez has oído hablar de la sostenibilidad?

☐ Sí ☐ No ☐No lo recuerdo

11. ¿Cuál es el significado para usted de sostenibilidad referida a la alimentación? Indique si está de acuerdo con las siguientes afirmaciones:

	Sí	No	No sé
La integración de la conservación de los hábitats naturales con la supervivencia del sistema económico			
Ser consciente de la calidad de vida en las decisiones de consumo diario			
Garantizar la salud y bienestar de los animales			
Conservación y protección de los recursos hídricos			
Reducción o eliminación de pesticidas y antibióticos en la ganadería y la agricultura			

12. Teniendo en cuenta los productos alimentarios sostenibles, por favor indique qué tan de acuerdo está con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	1 (Muy en desacuerdo)	2	3	4	5 (Muy de acuerdo)
Creo que los productos alimentarios sostenibles son más seguros que los convencionales					
En mi opinión, la calidad de los productos alimentarios sostenibles es alta					
La información sobre alimentación sostenible es pobre					
La información sobre alimentación sostenible es confusa					

13. Indique qué tan de acuerdo está con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
Yo generalmente no compro productos que incluyen conservantes					
Cuando trato con nuevos productos, no suelo mirar la lista de ingredientes					
Cuando trato con nuevos productos, la marca es importante para mi					
Creo que los productos ecológicos son demasiado caros					
Estoy dispuesto a pagar precios considerablemente más altos para la comida que tiene niveles más altos de calidad					
Prefiero comprar alimentos ecológicos					
Residuos de plaguicidas en las frutas y verduras son perjudiciales para la salud humana					
Los alimentos genéticamente modificados son un peligro para la salud humana					
Sabores y aditivos artificiales en los alimentos son perjudiciales para la salud humana					
El sabor de las comidas es más importante que los ingredientes					
El envasado de los alimentos es importante para mí					
Estoy cansado por las discusiones acerca de la nutrición y la salud					

14. Indique qué tan de acuerdo está con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
Prefiero consumir productos locales o de proximidad, cultivados o producidos cerca de donde vivo					
Suelo comprar algún producto de comercio justo					
Me fío poco de las marcas en general					
Confío en las marcas blancas					
No compro marcas ni productos producidos o fabricados por empresas que no sean responsables con el medio ambiente y la sociedad					
Participo en protestas contra las marcas poco respetuosas con el medio ambiente					
Leo las etiquetas de los productos con cuidado para saber sus ingredientes, elaboración, contenidos, calorías...					
Conozco la diferencia entre un producto ecológico y un producto natural, sano o de la huerta					
Consumo alimentos ecológicos porque es la tendencia y están de moda					

15. Indique qué tan de acuerdo está con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
Mi alimentación y la de mi familia es muy importante para mi					
Intento seguir una dieta mediterránea y tradicional					
Intento evitar las comidas preparadas					
Invierto más en mi salud que en mi aspecto					
Hago ejercicio con regularidad					
En lo que se refiere a alimentación siempre estoy buscando algo nuevo					
Cada vez consumo menos carnes y me oriento hacia una alimentación más vegetariana					
Intento darme un capricho alimenticio todos los días					

16. Media de **consumo de productos ecológicos**

☐Todos los días o casi todos los días

☐ 2 o 3 veces por semana

☐ 1 vez por semana

☐ Una vez cada dos o tres semanas

☐ 1 vez al mes

☐ Ocasional

☐ No consumo productos ecológicos

17. Teniendo en cuenta la elección de los productos alimenticios, son importantes los siguientes factores para usted? (1 poco importante, 5 muy importante):

	Poco Importante 1	2	3	4	Muy importante 5
Calidad					
Atención a la salud					
Seguridad alimentaria					
Origen en agricultura y ganadería ecológica					
Producido localmente o productos de proximidad					
Producido en mi propio país					

18. Indique la importancia que tiene para usted cada uno de los siguientes factores:

	Poco Importante 1	2	3	4	Muy importante 5
Respeto al medio ambiente					
Reciclaje					
Preservar los recursos naturales					
La promoción de la producción sostenible del medio ambiente					

19. Indique qué tan de acuerdo está con las siguientes afirmaciones (1 muy en desacuerdo, 5 muy de acuerdo):

	Muy en desacuerdo 1	2	3	4	Muy de acuerdo 5
Prefiero alimentos producidos localmente o productos de proximidad					
Si me das a escoger prefiero los productos de nuestro país					
Los alimentos del extranjero son siempre mejores					

Información general del consumidor

20. Año de nacimiento: ___________

21. ¿Cuál es su sexo?

☐ Hombre ☐ Mujer

22. ¿Cuántas personas viven en su casa? ____

23. ¿Hay niños en la casa?

☐ Sin niños ☐ Con niños

24. ¿Hay niños en la casa por debajo de 18 años?

☐ Sí ☐ No

25. ¿Cuál es su último nivel de estudios alcanzado?

☐ Sin formación

☐ Primaria

☐ Secundaria

☐ Universitaria

☐ Formación profesional o equivalente

☐ Otra ___________________________

26. La renta mensual familiar neta es:

☐ Inferior a 600 €

☐ 600–1.799 €

☐ 1.800–2.999 €

☐ 3.000–4.200 €

☐ Superior a 4.200 €

27. Situación laboral

☐ Estudiante ☐ Jubilado / pensionista

☐ Empleado por cuenta propia ☐ Empleado por cuenta ajena

☐ Función pública ☐ Sin ocupación y/o en paro

28a. ¿Donde compra la carne y productos cárnicos de cerdo?

☐ Carnicería tradicional

☐ Carnicería de supermercado o hipermercado

☐ Carne envasada en supermercado o hipermercado

☐ Otras (especificar): ___________________________

28b. Marque con una X los lugares donde compra habitualmente alimentos:

☐ Mercados/plaza de abasto

☐ Comercios de proximidad

☐ Supermercados de proximidad

☐ Cooperativas de consumo o similar

☐ Tiendas especializadas tipo gourmet

☐ Grandes superficies

29. Habitualmente, la frecuencia de compra de alimentos en el hogar es:

☐ Diaria ☐ Semanal ☐ Quincenal ☐ Mensual

MUCHAS GRACIAS POR SU PARTICIPACIÓN

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