Improving the quality of pork and pork products for the consumer

Q-PorkChains final report

September 2012

Improving the quality of pork and pork products for the consumer: Development of innovative, integrated, and sustainable food production chains of high quality pork products matching consumer demands.

Q-PorkChains was an integrated five-year project funded under the 6th Framework Programme for Research and Technological Development. The project started in January 2007 with 44 partners from 15 EU countries, 1 partner from Norway and the USA respectively and 4 partners from INCO target countries (China, Brazil, and South Africa). An open call in the 3rd year of the project supplemented the consortium with additional 13 partners, 1 research organisation and 12 Small and Medium Enterprises (SMEs) which further developed and applied Q-PorkChains' results in pilot projects.

The underlying rationale for the project is to be found in the dramatic changes in the international pork market over the past decade. Pork production is an important socioeconomic factor in the European Union (EU) as more than 20% of the world pork production is produced here (figure 1). Pork and pork products represent an important part of the diet in the EU. In several of the member states the proportion of pork exceeds 50 % of all meat consumed. But Europe faces increasing competition with regard to pork production and the subsequent processing and retailing of pork products. China, Brazil, USA and Canada are challenging the European Union's self-sufficiency and leading position in the pork sector. Additionally, European consumers are becoming increasingly sophisticated, demanding and powerful. They require foods that are of high quality, safe, diverse and healthy. Preferably they should be produced environmentally friendly and respect ethical aspects such as animal welfare issues.
In order to defend the position of the EU and to explore new production and market opportunities, Q-PorkChains addressed the need for developing innovative, integrated, and sustainable production chains, which produce high quality pork products, matching consumer demands. Thus, the project supports adding value to the total European production chain to ensure continued competitiveness and fulfilment of the demands of a user-directed market.

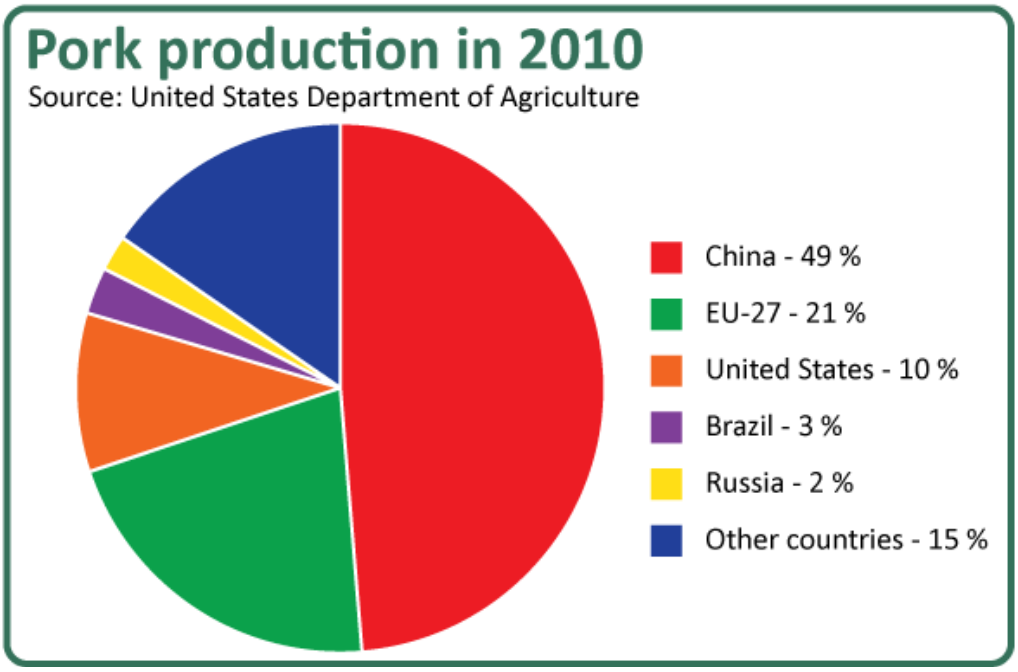

Figure 1: Pork production in 2010

During the last five years Q-PorkChains has investigated different aspects that characterise the entire pork production chain (figure 2).

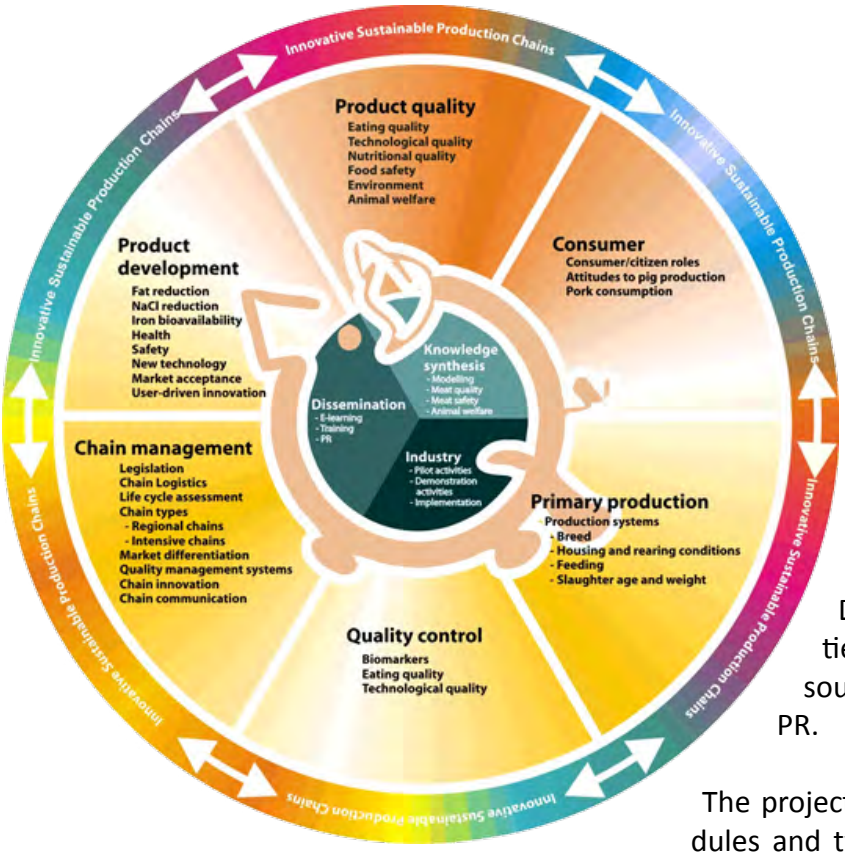

Figure 2: Scientific key activities of Q-PorkChains

Consumer and citizen roles focused on developing new tools for marketing and development of pork-based products. In the field of primary production, the diversity, flexibility and sustainability (environment, economy, societal demand) of farm level production systems were explored. Furthermore, Quality control focused on development and application of new and appropriate molecular control tools in pork production. In Chain management the focus was on integrated quality management and logistic and sustainable network optimization. Product development focused on innovative technologies for improved pork products, matching consumer demands with regard to quality, safety, nutrition, and convenience.

Three main project aspects depended on knowledge from the above mentioned pork chain areas. Concerning knowledge synthesis the aim was to synthesize the existing knowledge on pork quality, pork safety and animal welfare into prediction models. The industry mainly as SMEs aimed at facilitating cooperation with research organisations in pilot research and demonstration activities and develop inter-organisational collaboration along pork chains and networks. Dissemination of Q-PorkChains activities was performed via E-learning resources, training activities and general PR.

The project was structured in six research modules and two horizontal modules bridging the research community, the pork industry and the society at large (figure 3). The work has resulted in important achievements to strengthen the long-term competitiveness of the European pork sector.

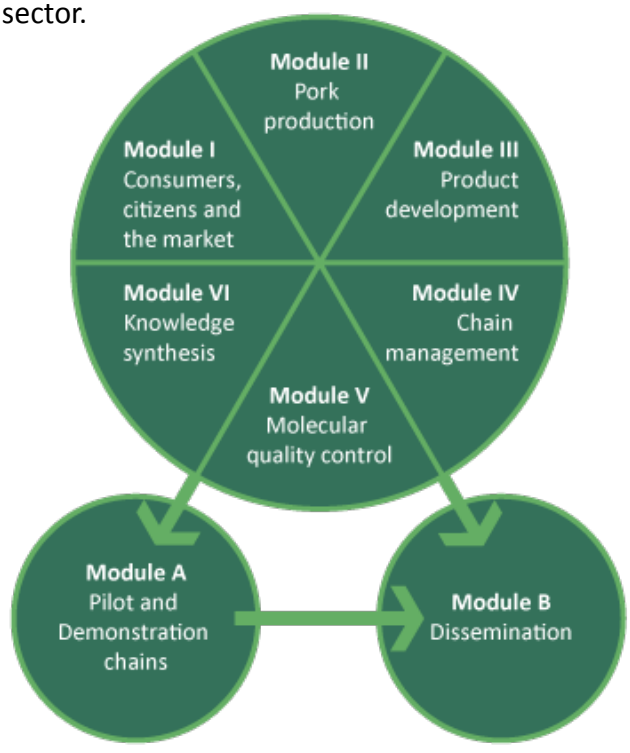

Figure 3: The structure of Q-PorkChains

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In this final report the project results are presented under themes which particularly well correspond to critical socio-economic issues related to the pork sector.

1. **Exploiting and enhancing diversity**
   - Differentiation of demand, page 5
   - Diversity of pork chains, page 8

2. **Enhancing sustainability**
   - Planet (environment), page 15
   - Profit (economy), page 19
   - People (society), page 21

3. **Managing quality**
   - Prediction of meat quality, page 22
   - Information and communication technologies for quality assessment, page 28
   - Quality assurance, page 30

4. **Q-PorkChains web-based platforms**

1 EXPLOITING AND ENHANCING DIVERSITY

Differentiation of demand

A comprehensive mapping of consumer attitudes and behaviour has been carried out in 5 European countries (Denmark, Germany, Belgium, Poland and Greece) as well as in China and Brazil. The results showed that pork is very popular and consumed as products that vary substantially and are processed to various degrees: from fresh meat, minced meat, marinated or stuffed to charcuterie type products. Product demand differs due to gender and individual taste but also with regard to the occasion when it is to be consumed: on the go, on weekdays or weekends or when inviting guests. There is also great variation with regard to culinary traditions in different countries and/or regions. Furthermore, demand depends on very personal preferences such as willingness to pay for quality, interest in cooking, either traditionally or innovative.

The Danish liver pâté segment (4%)
A small and exclusively Danish segment which is first of all characterised by its extraordinarily high consumption of liver pâté. This segment consume primarily low-value products (i.e. canned meat, minced meat and ribs).
The whole family participates in food preparation. Shopping, cooking and serving food are not perceived as the woman's but as a shared responsibility. This segment often makes shopping lists and have a relatively high acceptance of organic products.

The dry-cured ham segment (13%)
This segment consumes dry cured ham, cooked ham, fresh gammon roast and medallions more frequently than in any other segment. They tend to be very quality-oriented, and prefer fresh rather than canned, frozen or otherwise pre-packed pork products. The segment is characterised by an enjoyment from shopping and a belief that quality is more important than price. The segment is relatively largest in Belgium and Poland, but it also exists in Denmark, Germany and Greece.

The sausage and cold-cuts segment (9%)
This is a mostly German segment that consumes wieners and frankfurters, cold cuts, salami and shoulder more frequently than any other segment. For this segment taste is the most important quality and they like to cook, look for new ways to prepare meals and try new recipes. This is a less social segment than the others, they rarely go out for dinner or dine with friends.

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The ready-to-heat and barbeque segment (9%)
Ready-to-heat meals such as pizza and lasagne, pasta Bolognese, barbeque products such as skewers, mixed sliced meat, marinated pork and fresh sausages, as well as innards and cordon bleu are consumed more frequently by this segment than by any other segment. They are highly convenience-oriented and place little value on novelty and freshness. They have traditionalist gender attitudes, i.e. it is the women who is responsible for food shopping, cooking and serving. The segment is relatively largest in urban areas of Greece.

The minced meat segment (7%)
This is a predominantly Danish segment. Besides minced meat, other frequently consumed products include liver pâté and salami. High-value items (i.e. medallions, tenderloin, schnitzel and dry cured meat) are almost never consumed in this segment. The social aspects of food are important, and food is often prepared by the whole family. The segment dines often with friends. The members of this segment rarely experiment with new recipes or unfamiliar foods.

The low pork consumption segment (34%)
A low consumption of almost all pork products is characterising this large segment. The segment can be observed in all markets investigated in Q-PorkChains. People between 20 and 40 years from suburban areas seem to dominate. They love to shop but have no interest in cooking. When shopping they scrutinise product labels for product information. Snacking between meals and going to restaurants for dinner is highly accepted.

The tenderloin segment (25%)
Fresh, high-value products like tenderloin, medallions, collar roast and schnitzel consumed frequently by this large, quality-oriented segment. They have a high acceptance of organic products and an interest in novelty. To try new food and new recipes is more common in this segment than in most other segments. The segment is most dominant in Poland and Belgium, but can be observed in all markets.

Figure 4: Seven consumer segments (source: Olsen et al., unpublished data)

Figure 5: Picture from the brainstorming process

Pig production itself is a controversial subject. People hold views on the environmental impact and/or animal welfare issues related to mass pig production systems and preservation of small scale farms.
However, the project found that consumer attitudes (consumption preferences) and citizen attitudes (mass production, animal welfare) were only weakly linked.

Based on these results, ideas for new pork products have been generated in a brainstorming process and screened by the industrial partners (VION and Danish Crown). The most promising ideas were developed into product concepts and tested in four target markets (Denmark, Germany, Netherlands, UK) employing a newly developed concept testing method. This method allows not only measurement of expected product acceptance, but also optimization of the concept according to central dimensions of consumer quality perception. Minced meat containing vegetable proteins (Hackplus) and Nordic-inspired pork products were some of the products launched by VION and Danish Crown after the testing.

At VION the new product Hackplus is an outcome of the new concept testing method. Hackplus is a minced meat product with vegetable proteins. The product contains 30 % less fat and 30 % less cholesterol compared to traditional minced meat.

At Danish Crown they produced various products with spices or herbs from the Nordic Kitchen, for instance barbeque products after the use of the method.

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Diversity of pork chains

The various preferences for product specifications shown by different market segments in Europe today have led to a large diversity in the European production and processing systems.
The diversity arises from the pork markets' need of being competitive i.e. finding the most efficient way of adding value, thus fulfilling consumer and societal demands effectively and at minimal costs.

Production diversity

At farm level many different pig production systems exist.
A comprehensive inventory of the sustainability of 84 existing pig production systems was performed in 23 EU countries. This inventory identified 40 systems without a differentiating claim (conventional) and 44 systems with one or several claim(s) for differentiation (see table 1).

The results showed that the European pork production can be divided into three main systems:

1. Conventional systems characterized by intensive production targeting the standard quality market.
2. Conventional and Differentiated systems which cannot be placed in either system 1 or 3. Typically located in Northern Europe and The Netherlands.
3. Differentiated systems with an extensive production system focusing on animal welfare and/or meat quality.

From 5 of the 23 participating countries, 15 production systems (2 differentiated (differentiation is based on one or several claims) and 1 conventional systems per country) were selected for further analysis. The production systems were

Table 1: 84 production systems in 23 EU countries

40	No claim for differentiation	
44 (with at least one claim for differentiation)	**Claim**	**%**
	Welfare	68
	Eating quality	70
	Nutritional quality	25
	Environment	41
	Organic	25
	Local	9

Source: Professor Michel Bonneau, INRA

evaluated along 9 sustainability dimensions within the three main sustainability pillars; People (Society), Planet (Environment) and Profit (Economy) as pictured in Figure 6. The analysis is further explained in the section "Enhancing sustainability" (page 14).

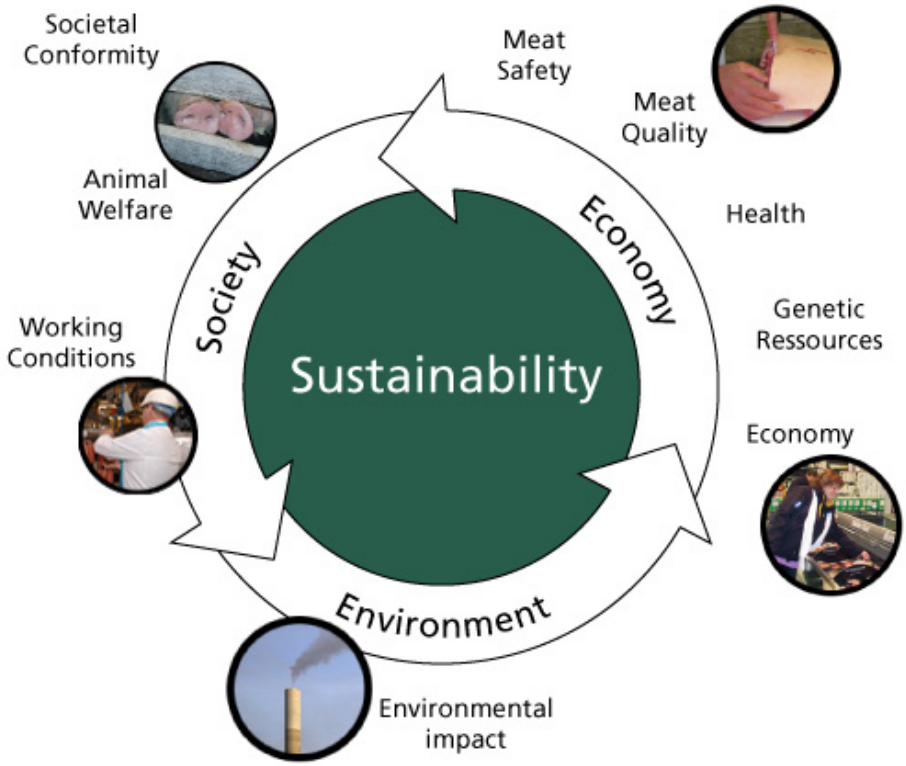

Figure 6: Sustainability issues for evaluation of production systems

An additional inventory was performed on pork chains in China, South Africa and 6 European countries (Hungary, Greece, Spain, The Netherlands, Germany and Denmark) the conventional pork sector represent by far the largest market share. To stay competitive an increasing differentiation of products was though observed in these pork chains.

To accommodate the demand for differentiation, specialized pork chains aiming at niche or regional markets were found in most European countries. These chains distinguish themselves on pig breed and/or genotype of pork product (e.g. Ham of Bayonne in France, Jamón Ibérico in Spain, or Mangalica pork in Hungary) or on quality management and organisation (such as Eichenhof chain in Germany or ''De Hoeve'' in The Netherlands). In North-Western European countries coordination is facilitated by sector wide private quality management standards such as QS (Qualität und Sicherheit) in Germany, IKB (Integrated Chain Management) in The Netherlands or Label Rouge in France, and by sophisticated inter-company quality management and information systems.

In Q-PorkChains, key success factors for the organisation and functioning of pork chains aiming at niche markets were identified.

1. Companies, when formulating their strategies, should consult closely with key stakeholders, such as (regional) governmental organisations, sector organisations and outlets

SIXTH FRAMEWORK PROGRAMME

(retailers or local butcher organisations).

2. Companies should be 'embedded' in their regional and/or local environment. They should engage in regional development and collaborate closely with consumer and/or citizen associations.
3. Companies should develop and use management support tools to assess risks concerning supply sufficiency and consult (regional) government policies.

In a pilot project, run within Q-PorkChains, it was obvious that management factors are of key importance for the success of niche pork chains.

Shop in Karditsa, Greece

Greek niche pork chain

The success factors identified for a Greek niche pork chain are also the management team's vision and drive. Moreover, good contacts exist with local restaurant owners, who buy and serve the meat. The use of a well-known label is also seen as a key success factor in this chain. In general, collaboration and communication are considered essential success factors.

German niche pork chain

Key factors identified for a successful German niche pork chain are the vision, drive and persistence of the management team. Another strong point, in line with the success factors identified above, is the communication strategy of the organisation. Much effort goes into developing clear and attractive labels and packaging for the meat products targeted at the regional market. Moreover, several regional shops have been established where consumers can buy a variety of regional products. Good collaboration with other regional producers is essential and good collaboration also exists with restaurant owners.

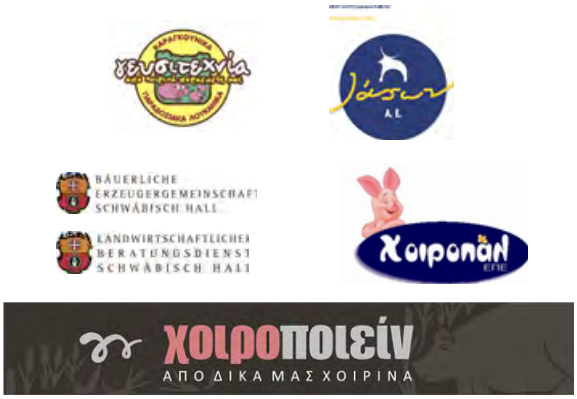

Figure 7: Logos from the involved SMEs

The toolbox for product development is web-based (http://qpc-toolbox.org/). It enables SMEs to obtain information on methods to support their product development process. The toolbox covers opportunity identification, idea generation, idea screening, concept testing, product testing and market testing. Each of these methods was described and screened for use by SMEs in the pork sector. The toolbox was developed on the basis of real data obtained in cooperation with leading pork processing companies.

Diversity at processing level

One of the focus areas within Q-PorkChains was product innovation as a way to increase competitiveness of the European pork sector.

Within the project a toolbox for product development targeting SMEs was developed. The purpose of the toolbox was to incorporate creative techniques and idea generation tools that SMEs can apply without help from expensive external actors (business consultants etc.).

To develop pork products matching consumer demands in relation to quality, nutrition and convenience innovative technologies such as High Pressure Processing (HPP) and Bioactive Packaging were used.

a) Development of healthier products

Salt is normally added during processing of cooked ham or comminuted pork products but ways of reducing salt content in these products are in focus because of human health issues. However, innovative technologies are needed in order to reduce salt content and maintain good technological and eating quality (i.e., texture and juiciness). Q-PorkChains investigated the possibility of substituting and/or lowering salt and fat content in popular pork products, such as ham and sausages without compromising taste. The salt reduction was made pos-

Figure 8: Products developed in Q-PorkChains with reduced salt and fat content

sible by combining a holistic theory on water binding capacity, a mechanistic study on interaction between ions and meat proteins and the relationship between water content, water activity (aw) and meat structure.

> Pork fat is naturally structured as tri-acylglycerols (TAGs). By enzymatic treatment TAGs can be converted to diacylglycerols (DAGs). This conversion result in changes of fat physical and chemical properties, which may lead to improved technological quality characteristics of fat. As an example transformation of TAGs to DAGs in lard prior to application in meat products was found to affect the product texture. Another benefit of DAGs is lower fat accumulation in the human body compared to TAGs.

The nutritional quality was furthermore increased by using innovative technologies and addition of health promoting ingredients in cooked ham, breakfast sausages and fermented sausages without deteriorating the sensory, technological and microbial quality. Along with the health benefits associated with flavonoid extracts (rosemary-pomengranate and grape seed extracts), phytosterols and prebiotic dietary fibres (inulin) this research aimed at selecting suitable functional ingredients for the development of healthier breakfast sausages with enhanced sensory and technological benefits. Target flavonoids and phytosterols showed satisfactory stability in fermented sausages.

Among the tested products the following are of particular interest:

- **Use of seaweed as a health promoting agent:** Two types of seaweed (Wakame and Dulce) were tested. They resulted in cooked ham with distinctly different appearances. A consumer panel was asked to associate the products with emotional responses. The products were described as exciting, surprising and exotic but also slightly boring as the appearance of the product did not match the expectation the consumers with regard to the taste of the product.
- **Prebiotic fibre (inulin):** 2.5 % inulin was added to breakfast sausages resulting in a product with 23% less calories. These sausages had similar sensory consumer acceptability as the standard full fat sausage.
- **Reduced salt ham product:** Reducing the salt content in cooked ham from 2.1% to 1.5% had no detrimental effect on technological or sensory quality if 0.3% phosphate was added and processing was performed at 2°C.
- **HPP technology:** Breakfast sausages containing 1.4% salt compared to the normal 2.5% were produced by combining minimal processing and an innovative hurdle technology (high pressure processing at 200 MPa). The results were stable low-salt pork products with high sensory, nutritional and microbiological quality acceptable to the consumers and without a noticeable change in composition, emulsion stability, lipid or microbial stability.

- **Tomato pulp to reduce nitrite:** The influence of the addition of tomato pulp powder on the reduction of nitrite content in luncheon pork rolls was investigated. A 50% reduction in nitrite content could be achieved by adding 1.5% tomato pulp powder without compromising the pork rolls sensory attributes.

b) Development of convenience products

Convenience is one of the major market trends in pork products. Within Q-PorkChains, as a potentially popular example of such a product, safe and acceptable sliced cured pork carpaccio was developed by combining reduction in aw and/or pH, and HPP at 600 MPa. Tenderloins from black Mallorca pigs were better suited for the production of high quality slightly dried pork carpaccio than those from intensively reared pigs. Safety of salt and/or fat reduced sliced fermented sausages was improved by the combination of HPP and active packaging. The effect of HPP on sensory characteristics increased with water content. Additionally, antimicrobial biodegradable packaging systems providing safer sliced fermented sausages were developed.

Figure 9: Top; Pork Carpaccio of Black Majorcan Pigs (left), Black Majorcan Pigs from Son Forteza, Mallorca (right), Bottom; Black Majorcan Pigs from Son Forteza, Mallorca

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2 ENHANCING SUSTAINABILITY

Sustainability is a global concept which is classically considered along the three main pillars "Planet" (Environment), "Profit" (Economy) and "People" (Society). The Q-PorkChains project investigated these three pillars separately, along 9 themes as described below (figure 10), but it also conducted studies on the overall, integrated sustainability of pork production systems.

The environmental load of pork products has gained increased attention among consumers and the society at large. In particular the impact of meat production/consumption on global warming is of considerable interest among consumers and consequently among actors in the food chain.

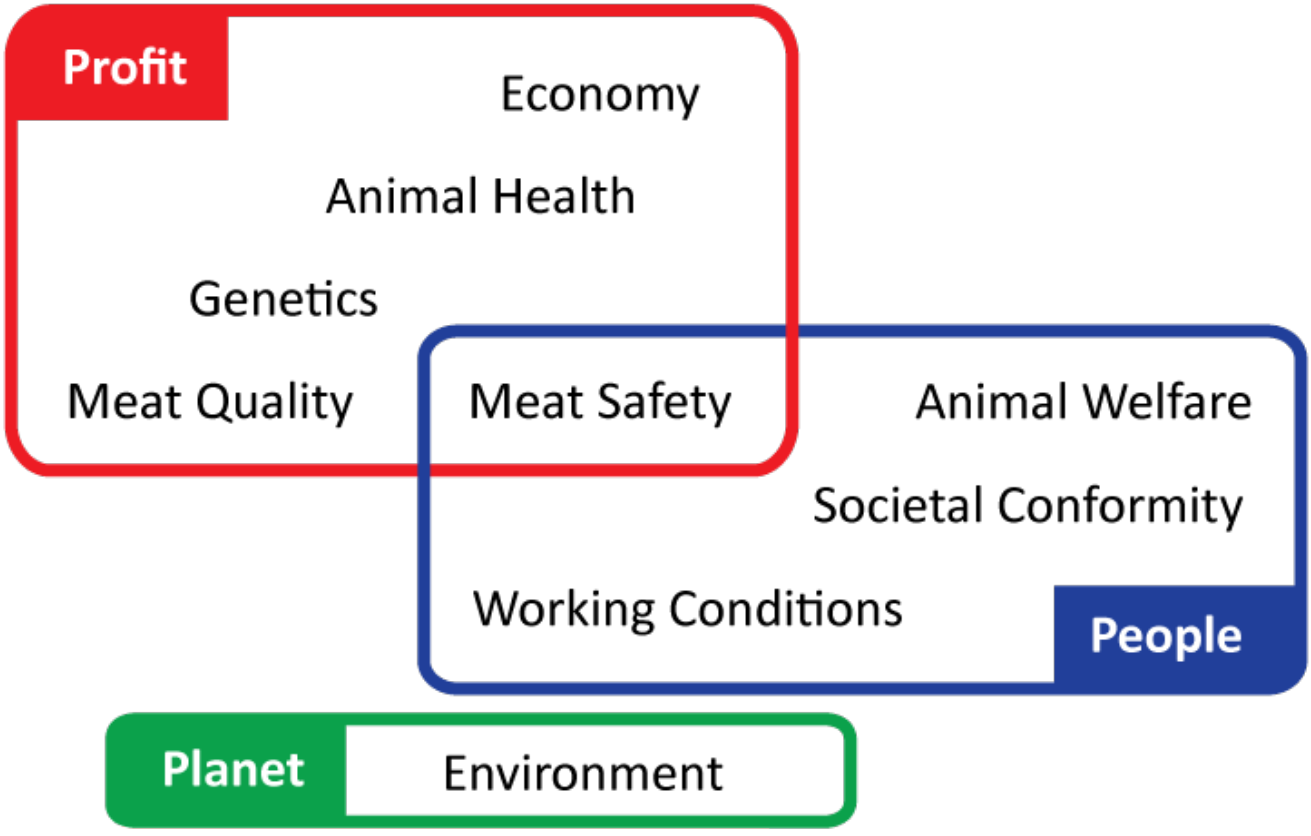

Figure 10: Sustainability themes within the pork production system

Planet (Environment)

It is estimated that approximately 25% of the human impact on global warming is related to food consumption. Meat and dairy consumption alone account for 14% of the global warming effects of the total economic activities in EU. Thus meat consumption is a determining factor for the overall environmental impact, and highlights the importance of taking these aspects into account in all decisions in the food chain and in the consumption pattern of the consumers.

a) Environmental impact of pork production systems at farm level

Life cycle assessment (LCA) is the most universally approved method to evaluate the environmental load of production systems. LCA is very well developed for purely industrial production, but less developed within food and farming. A considerable part of the environmental load is related to the farming activities. The LCA approach allows the formation of environmental indicators that integrate factors impacting all along the chain. For instance, the contribution to global warming is therefore the sum of impacts coming from emissions of CO2 (related to i.e burning of fossil fuels used for transport), methane (originating from manure management) and laughing gas (coming from i.e fertilizer use).

The term conventional applies to farms with lowest possible costs and standard meat. The adapted conventional farms have many similarities with conventional ones, but they have extra rules to accommodate claims on societal or consumer expectations.

A LCA methodology was developed to enable the assessment of the environmental impact of 15 contrasted pork production systems in Denmark, France, Germany, Netherlands and Spain. The analysis included 5 conventional (C1-C5), 5 adapted conventional (AC1-AC5), 2 organic (O1-O2), and 3 traditional (T1-T3) production systems, considered at farm level. The adapted conventional systems are close to the conventional ones but have a few specifications concerning responses to societal expectations (such as animal welfare). All environmental impacts from feed production to delivering pigs to the slaughterhouse were incorporated. The results of environmental impact was calculated for global warming (GW, kg CO2-eq), acidification (Acid., kg SO4-eq), eutrophication (Eutro., kg PO4, eq), energy use (En., MJ) and surface use (Surf., ha). The impacts were based on kg pig produced or ha of land used. In figure 11 (next page) the results are summarised for the 15 contrasted production systems.

Very differentiated production systems using traditional breeds for high quality products or organic production showed less local impact (eutrophication, acidification per ha) but more global impact (acidification per kg pork, climate change, use of non-renewable energy, land occupation). There was however high variability within type of system. See for example the T3 system that is close to the conventional ones and the AC-3 and AC-5 systems which have much higher impact on global warming than the other AC systems.

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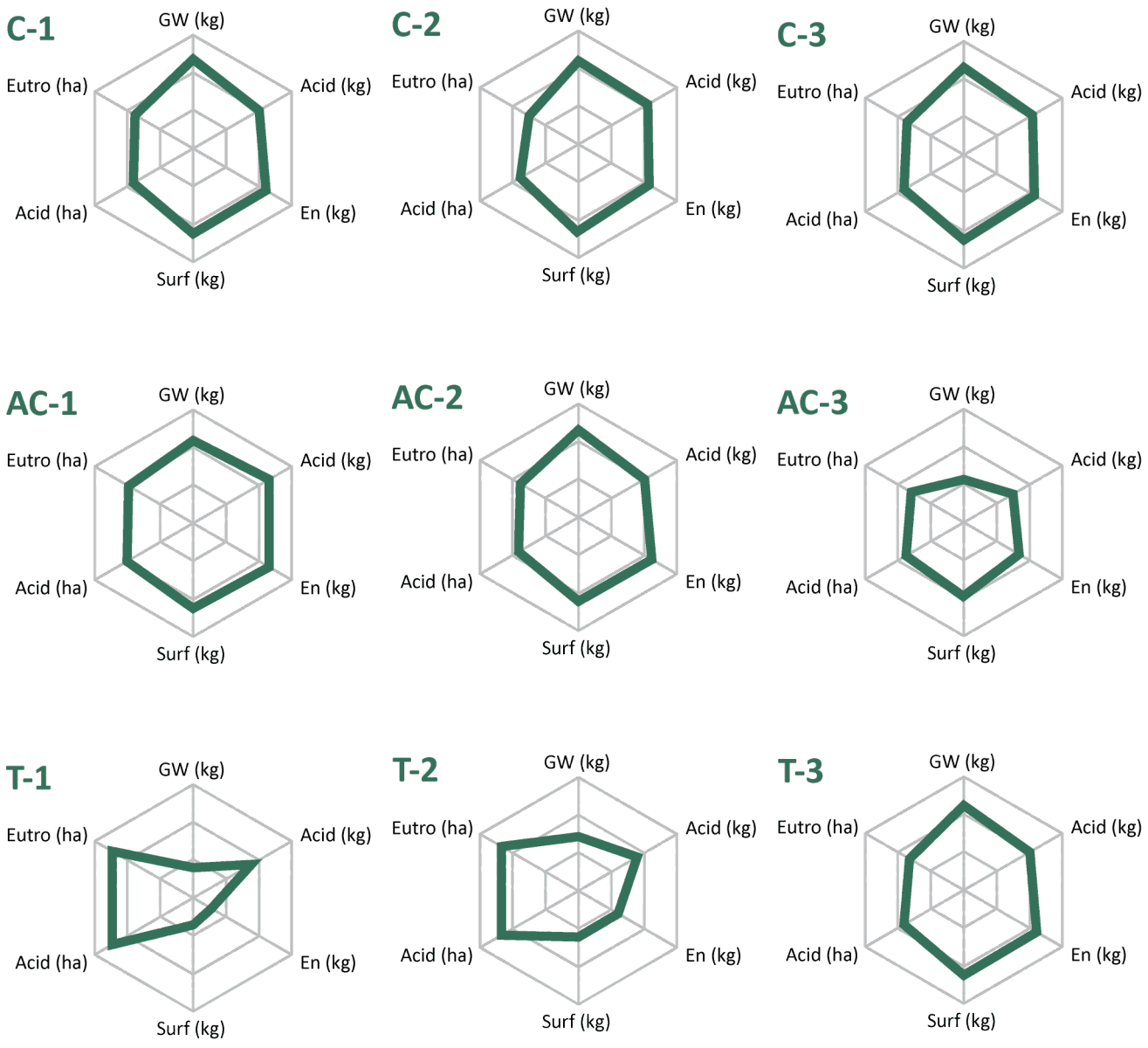
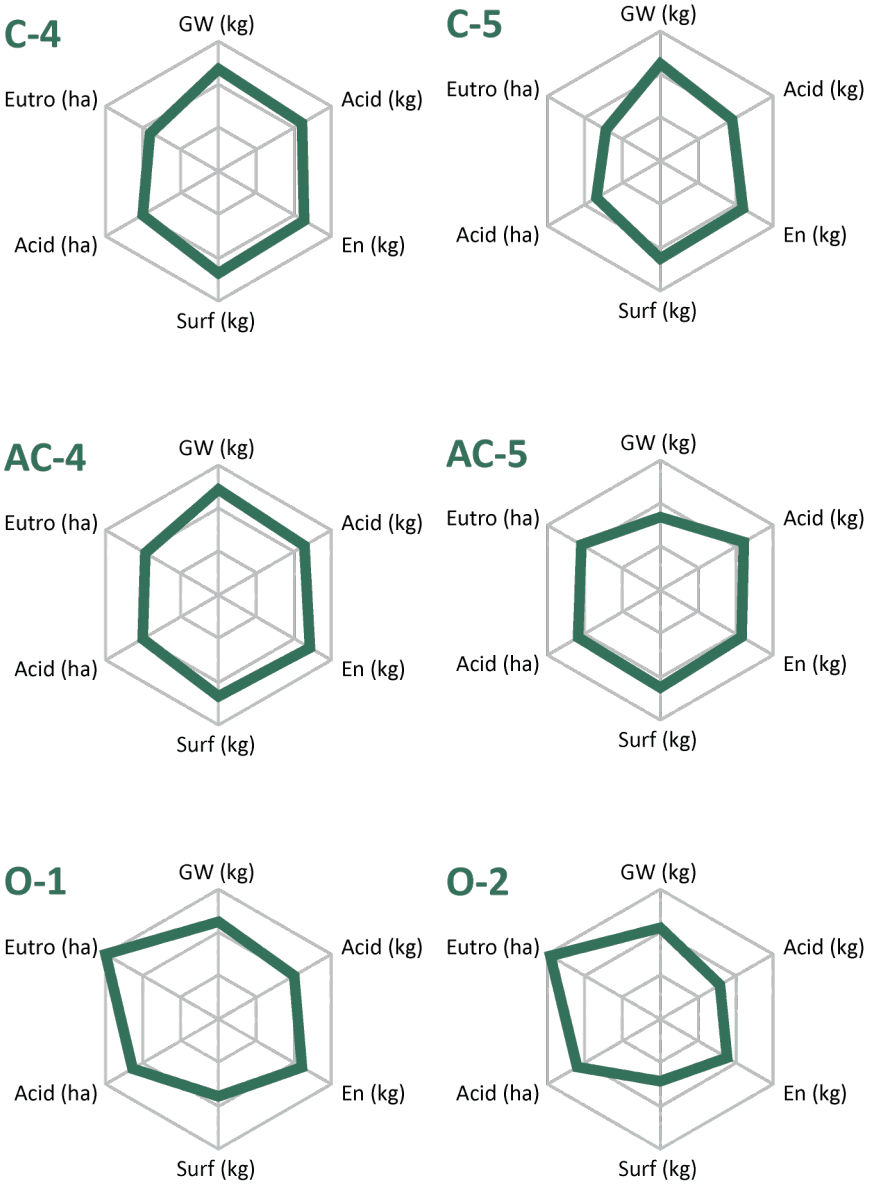


Figure 11: Results on the environmental impact of 15 pig production systems (C1-C5, AC1-AC5, T1-T3, O1-O2). For all traits, higher score means better sustainability, i.e. lower environmental impact.
GW (kg) = Global Warming measured in kg pig produced, Acid (kg) = Acidification measured in kg pig produced, En (kg) = Energy use measured in kg pig produced, Surf (ha) = Surface use measured in ha of land used, Acid (ha) = Acidification measured in ha of land used, Eutro (ha) = Eutrophication measured in ha of land used.



b) Balance between environmental impact and production costs

The economically most important environmental impact factors are nature occupation (land use for feed production), global warming, and respiratory inorganics (ammonia emission impacting on human health). Acidification of manure and reduced feed use represent the most important improvement options regarding environmental costs in monetary terms.

To ensure a good balance between environmental impact and production costs, a model for the optimization of feeding strategies was developed in Q-PorkChains. The model is based on two communicating computerized units, one unit containing information on the feed ingredients and one unit containing information regarding the animal. The feed ingredient unit is a least-cost feed formulation unit including information on nutrient content, their environmental impact and cost. At least three different feed ingredients can be optimized at the same time which makes the model suitable for phase feeding.

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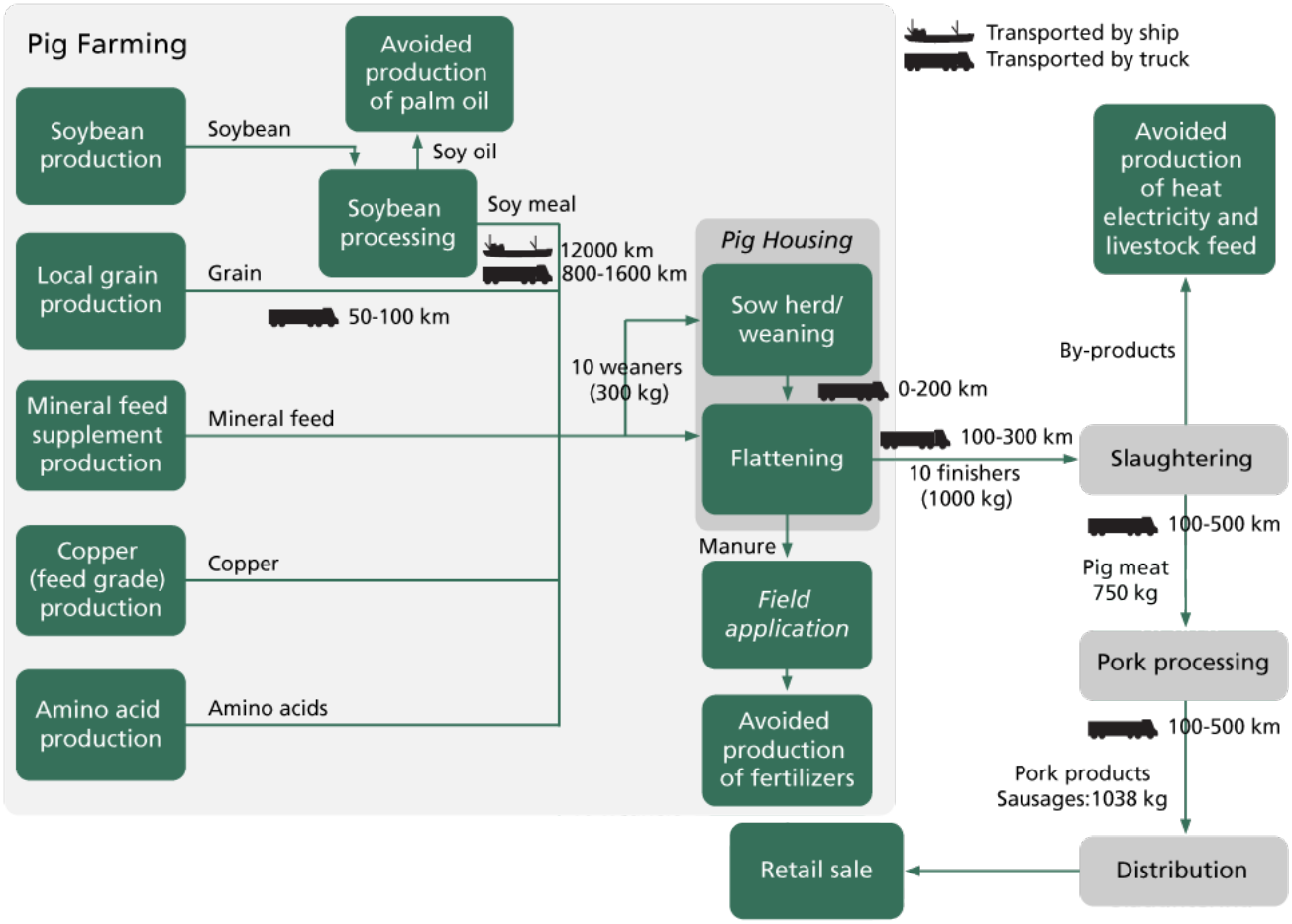

Figure 12: Pig farming and sustainability, source: John Hermansen, University of Aarhus, Denmark

The animal unit describes the pork production system including the prediction of excretion and emission from the animal and the manure. The model can be used for a wide range of different pig production systems and many options for changing animal management, performance, type of feed and manure management are available.

The model calculates the environmental impact according to the input concerning the feed composition, animal performance and production systems. It is currently under revision, but for interested parties the procedure of calculation will be published in a scientific paper after peer-reviewing.

Profit (Economy)

Pork production is only sustainable when it can ensure a living for those involved in the pork chain; in other words, pork production needs also to be profitable. Profit can be evaluated at the level of single actors, here at farm level and in the slaughterhouse, and at the chain level.

a) On farm

The technical and economic performance of pig farms was evaluated in 12 of the above-mentioned production systems. The farms were evaluated using the IDEA (Indicateurs de Durabilité des Exploitations Agricoles) method (http://www.idea.portea.fr/), which is a comprehensible, reproducible and pragmatic tool already validated in the field. However, IDEA is not specific for pig production, and therefore Q-PorkChains experts estimated if indicators and benchmarks were appropriate to use here and adapted them where necessary accordingly.

Most production systems had poor economic results. But two traditional systems performed economically better due to high marks for specialisation and transferability. Three conventional systems also had good results, particularly due to low reliance on subsidies and high economic viability.

b) Slaughterhouse

Today's consumers increasingly demand products that are produced sustainably and ethically correct. As a result, businesses need to address sustainability and social responsibility issues and find a proper balance between people, planet and profit (PPP) aspects of their production chains. Software tools can play an important role in mapping out the current state of PPP aspects along the production chain, and in the design and evaluation of improvement options. There are indeed many tools that claim to be useful for sustainability and social responsibility considerations. Yet, a tool that addresses all three aspects of value creation holistically and facilitates discussion is missing. In Q-PorkChains the development of such a tool, called QChain, was based on ideas from soft systems methodology and inputs from a multidisciplinary team of experts and managers. The tool is intended to support group discussions, particularly during the early stages of innovation processes aimed at improving PPP aspects of production chains. It enables users to visualize the essential elements of the current production chain showing the current aggregated PPP value, and explore and compare possible future production chain scenarios and the corresponding PPP value. QChain's visualization helps discussants get a rich appreciation of the current and future scenarios, while the semi-quantitative 'what-if' analysis and scenario comparison enables them to have objective discussions.
The tool is available at: http://www.ldi.wur.nl/UK/Products/Toolbox+Value+Creation/

QChain tool
The basics of the tool have also been described in: Kassahun et al. (2011), Journal on Chain and Network Science, vol. 11, issue 2.

A decision support tool has been developed to investigate opportunities for production cost reduction through relocation of production within Europe. Data on transport costs,

SIXTH FRAMEWORK PROGRAMME

Profit can also be enhanced just by optimizing the information flow in the value chain. Several tools have been developed within Q-PorkChains in order to optimize the information flow within the chain, i.e. an information system on the health of the pigs. Read more about the different tools on page 28-29.

production costs and feed data have been defined and incorporated into the model. The scenario calculations reveal major reduction opportunities in cost as well as in CO2 emissions by means of relocation of different chain activities. The results show that regional advantages in some parts of the supply chain can be combined with moderate results in other stages of the chain within one country. For example piglet production in Denmark is very cost effective, but slaughter and processing is expensive.

The figure below shows three scenarios: one based on cost optimization, one on CO2 eq. optimization and one on combined optimization. Results of this analysis show that both costs and CO2 emissions can be reduced if the production takes place in the country with the lowest overall costs (in most scenarios Poland).

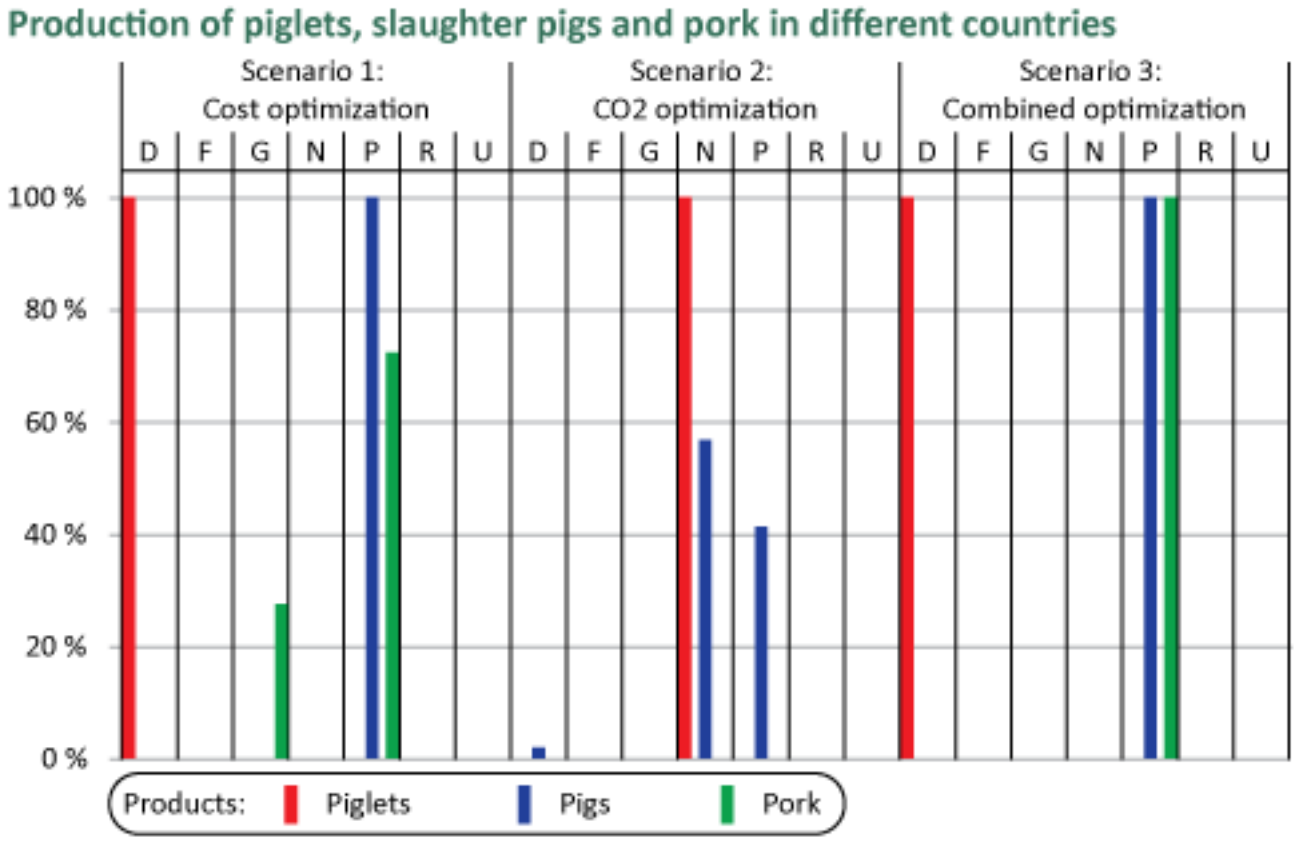

Figure 13: Optimization in the supply chain. D = Denmark, F = France, G = Germany, N = The Netherlands, P = Poland, R = Russia, U = United Kingdom

People (Society)

The People aspect of sustainability includes how well pork products meet consumer demands and pig production systems meet societal expectations.

In Q-PorkChains, a study of citizens attitudes in relation to pork production revealed that environmental concerns are, next to those related to animal welfare, most frequently discussed in connection with pork production and there is a market segment for environmentally-friendly produced pork. The study was conducted in five EU countries plus China and Brazil. The environmental concerns and animal welfare issues were more important than issues concerning intensive vs. extensive farming and considerations about quality and health. However, for the majority of respondents, these attitudes were relatively weak. In the five European countries 15.4% of the population was identified as environmentally conscious citizens for whom environmental impact of pig farming was a major concern, in figure 14 an overview of the four segments is illustrated.

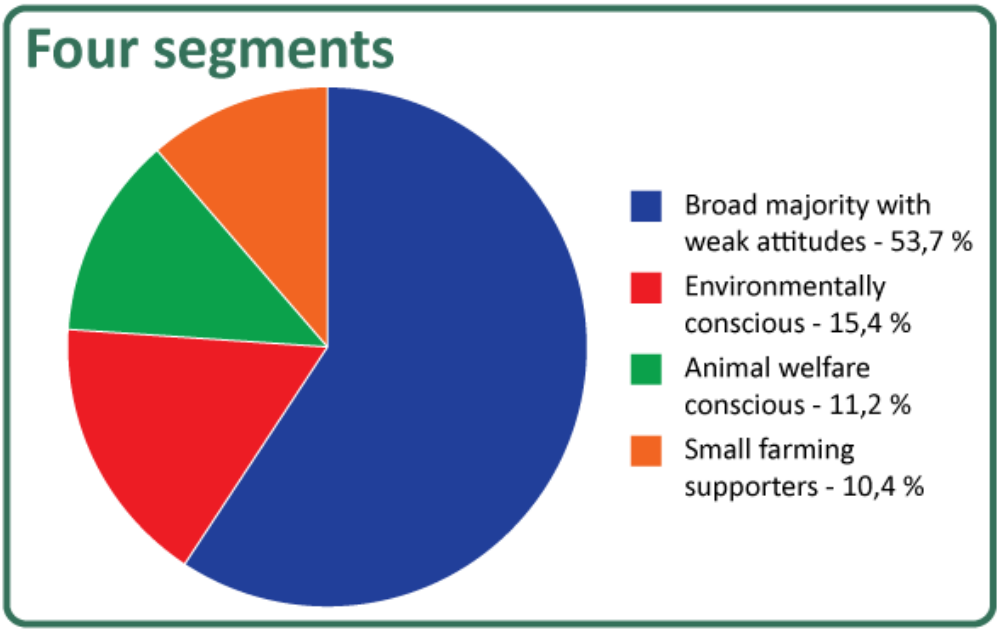

Figure 14: Citizens attitudes can be divided in four main segments

A societal conformity enquiry performed among experts from within the production system (system owners, agricultural journalists, farm advisers etc.) and outside the production system (representatives from NGO's and general journalists) confirmed the high societal focus on animal welfare. Interestingly, there were considerable differences between the experts' own views and their expectation of the public views. Virtually all respondents expected differentiated systems to be more overall sustainable, with limited draw backs for specific sustainability themes. The overall judgement of the main sustainability categories (People, Planet, and Profit) of the conventional systems were evaluated as rather neutral by people from within and clearly negative by people outside the sector.

In Q-PorkChains several studies were performed to enhance the welfare of:

- Non-castrated male pigs
- Sows
- Majorcan Black pigs

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3 MANAGING QUALITY

Prediction of Meat Quality

The quality of pork and pork products consists of numerous, interlinked and dynamic factors. They affect meat quality all along the pork production chain from the farm to the consumer and therefore make quality assessment a complex and expensive exercise. For several years a need to develop non-invasive, reliable, quick and easy to handle prediction tools has been expressed. In Q-PorkChains, tools for prediction of eating quality characteristics (e.g. tenderness) and technological quality (i.e. water-holding capacity (WHC), pH, meat/fat colour and total fat content) along the pork chain have been explored. In addition, interactive web-based models predicting technological and sensory pork quality, based on genetic background, production characteristics, animal treatment and slaughter technology were developed (QPC-models, page 32).

a) On farm prediction

A rapid test was developed based on the circulating level of Acute Phase Proteins (APPs) in the blood. The test predicts animal health and therefore allows a sequential health analysis of pig stocks on farm. APPs are proven indicators for animal health and hence indirectly imply that the rapid test can be used as a predictive tool for food safety, animal welfare and production costs. Based on the de-

APPs are plasma proteins that modify their concentration following infection, inflammation, trauma and/or stress. The APP assay can identify herds where poor hygiene, lack of surveillance, poor vaccination responses or other factors have led to immunological stress and a reduction of feed conversion.

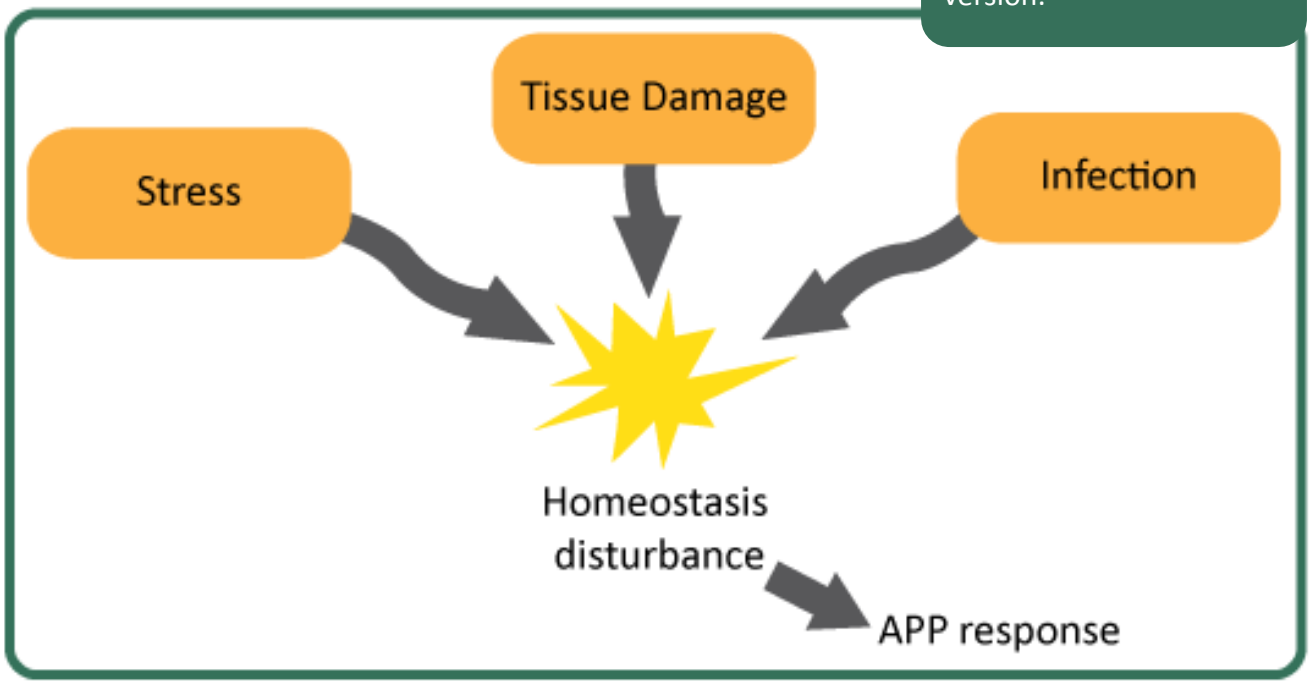

Figure 15: Factors causing an acute phase response

An e-learning resource on how to use the APP test is freely available from the open learning platform www.porktraining.org

Figure 16: An example of the rapid test for Acute Phase Proteins

veloped rapid test and other new technologies for detection of APPs an inspection concept for quality management was designed which can be incorporated into quality assurance systems. The level of APPs might also act as a useful indicator for the prediction of meat quality traits.

The main benefits for the industry are:

- Quality management; the improvement of pig health and the resulting welfare status can be measured.
- Risk assessment; Farmers and the pig industry can identify and breed healthier and more productive pigs. Risks can be quantified easier and information on disease surveillance to pig producers will be enhanced.
- Information flow; Communication between actors in the production chain can be improved.
- Meat quality; Consumers will benefit from healthier pigs through improved meat quality and food safety.

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b) Prediction at the processing line

From a technological point of view, knowing the total fat content allows industry to classify meat cuts in different groups and assign them to the most appropriate process. The fat content affects the amount of absorbed salt, the diffusion mechanisms and the processing weight losses and, consequently the salt concentration in the final product. Moreover, there is also a great interest from a nutritional point of view as total fat content and fatty acid composition has been shown to affect human health.

In the following prediction of water-holding capacity, total fat content and the drying proces is described.

Water-holding capacity

Water-holding capacity (WHC) is one of the most important pork quality traits as it improves the sensory appreciation of pork by consumers, affects the amount of saleable meat by reducing purge loss, and increases processing yield of the further processed products. In Q-PorkChains near-InfraRed (NIR) sensor technology was used to estimate WHC in pork hams and the potential of NIR as a sorting tool was evaluated. The techniques proved to be highly useful for the prediction of WHC at the slaughter line.

Total fat content

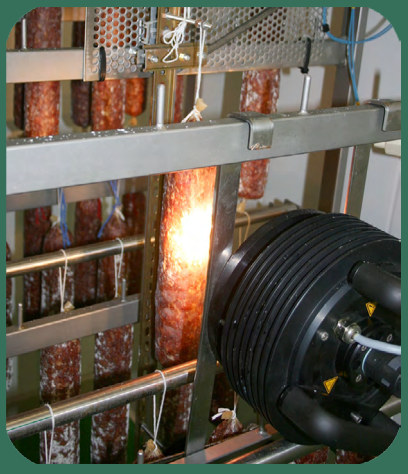
Information about the total fat content allows the industry to sort meat cuts and assign them to the most appropriate subsequent processing. Fat content of green hams is a key issue for dry-cured ham processors as it affects salt diffusion, absorbed salt, and processing weight losses. Thus, the fat content is a marker of green ham suitability for dry-curing.

Several on-line non-invasive grading systems for the determination of fat content were evaluated in Q-PorkChains: ultrasound (AutoFom), which is currently used for carcass classification at slaughterhouses; magnetic resonance relaxometry (NMR); electromagnetic induction (ham-grading system) and X-ray attenuation (X-ray inspector). In table 2 on the next page you can see an overview of the grading systems evaluated in Q-PorkChains.

Drying proces of fermented sausages

Drying of fermented sausages normally requires the supervision of an expert who manually readjusts air temperature and the relative humidity set-point of the drying process to obtain the desired final meat product. In Q-PorkChains an on-line instrumental measurement of parameters related to the expert evaluation was studied. The on-line technique is useful for the improvement of the control system to avoid crust formation. NIR spectroscopy enables a rapid, simple and on-line determination of different meat properties on the surface, like moisture content and water activity. The results confirmed that NIR allows the control of the drying process through on-line control of the water activity and the moisture content of the salami surface.

Temperature and relative humidity sensors on the dryer



NIR measuring aW on the product

Sausages in the dryer

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Table 2: Overview of online non-invasive grading systems for total fat content

	Method	Country	Result	Industry
 AutoFom system at the slaughterhouse	AutoFom	Italy Italian Heavy Pigs (total fat content 12-31% in green hams)	The calculated calibration model is preliminary, further analysis is needed for validation	Can be a promising tool for online classification at industrial level (but more analysis is required)
  MRI apparatus ARTOSCAN and the dedicated coil for Relaxometry	NMR-Relaxometry NMR-Imaging (MRI)	Italy Loins of pigs from Spain and Italy	Gives Fat/Water ratios that corresponds to Fat/Water ratios determined by chemical analysis	Promising tool, but further measurements are required. Dedicated apparatus should be manufactured for the analysis of larger samples.
 Ham-grading system	Ham grading system (technology: electromagnetic induction)	Spain Iberian, Mangalica, Duroc and Large White pigs (total fat content 15-40% in green hams)	Can predict overall fat content of raw hams Total fat prediction errors obtained were lower than 1.7% in all green hams.	Can be used to classify hams online at an industrial level
 X-ray inspector	X-ray inspector (technology: X-ray attenuation)	Spain Iberian, Mangalica, Duroc and Large White pigs (total fat content 15-40% in green hams and 5-17% in loins)	Can predict overall fat content of raw hams and loins	Further studies are needed to improve the fat prediction to classify hams online at an industrial level

What's next?
Following the results of Q-PorkChains the industry now should translate the gene or protein markers for meat quality found into ready-to-use tools for prediction of the most important meat quality traits.

c) Quality control using biomarkers

To increase the quality of both fresh and processed meat, slaughterhouses need rapid and low cost tools to determine meat quality of individual carcasses. Q-PorkChains used explorative techniques like omics to identify potential biomarkers for quality control. Several proteins and genes were related to meat quality traits but changes in one protein or gene only explained a small percentage of the variation in meat quality whereas when more genes were included in the model a more precise prediction of the meat quality traits could be performed. Q-PorkChains found candidate gene markers for intramuscular fat (marbling), texture, and parameters determining the final quality of dry-cured hams. Proteomics revealed candidate biomarkers for texture and colour of dry-cured ham and texture, colour, drip and cooking loss of cooked loin. Also here the results indicate that a combination of markers instead of a single protein should be considered for the further development of quality control tools. Primary porcine muscle cell cultures were used to investigate the functionality of some of the genes that could serve as markers for meat quality traits. Genes were knocked-out by siRNA technology and simultaneously changes in muscle development and expression of genes were identified. This clearly helps to increase the understanding of meat quality regulation.

What is Omics?
The complete sequencing of the genome has started a new research area called 'omics'. Instead of studying one protein or one gene at a time it is now possible to study whole organelles or biological pathways simultaneously. The term 'omics' refers to the comprehensive analysis of biological systems. A variety of 'omics' subdisciplines have emerged, each with their own set of instruments and techniques. The 'omics' technology that has driven these new areas of research consist of DNA and protein microarrays, mass spectrometry and a number of other techniques that enables high-throughput analysis. New 'omics' technology is developing constantly, however, among the more wellknown are 'Transcriptomics' and 'Proteomics' that are focusing on the genome and the proteome, respectively.
Reference: www.omicsworld.com

Figure 17: Picture from the biomarkers session at the final Q-PorkChains conference

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Information and communication technologies for quality assessment

Meat quality assessment is valuable for improved risk assessment, decision support and competitiveness. A centralised information and communication database was developed and implemented for health and safety control. The database, Wikiporc system, enables veterinarians and advisory services to store and retrieve data on animal health and meat safety. Medicine use is explicitly recorded, waiting times can be checked, while also farm performance can be measured in terms of the number of healthy pigs delivered to the slaughterhouse. Thus, feedback can be given to several responsible actors in the pork supply chain, in particular feed technicians, veterinarians, and farmers. Web-based communication like the Wikiporc system helps improving information exchange and online decision making in supply chains as well as at slaughterhouse level. Q-PorkChains showed that such an integrated chain oriented information and communication system leads to organisational changes. However, at management level support for further development and implementation of the system is crucial to ensure the continued optimisation. Step by step addition of user groups to the system requires willingness to adapt to these new work procedures and to communicate with other actors in the chain. However, it was shown that user resistance is gradually reduced when they became convinced of the system's potential.

Online analytical processing tools were developed and standardized to support services for evaluating product quality of finishing farms. Advisors used these software tools online on the farm with the help of a new mobile office. Online check lists have been developed and implemented to assess the performance and health parameters of piglet production by farm veterinarians. In addition, an animal health monitoring has been set up to improve the status of Salmonella and PRRS virus of piglets.

One of the chain oriented mutual critical control points are veterinary findings during the meat inspection at the slaughter line. New concepts for the harmonisation of veterinary findings in meat inspection can also support the assessment of meat quality. In this regard, veterinary findings deliver upstream and downstream information about the health and safety status of pigs and carcasses. To manage the upstream information on a farm and to compare it to others, a concept for a harmonised approach of inspection and digital documentation of test results of lungs, livers and other organs has been developed and tested. New online assessment software tools are provided. They are user-specific to farmers, veterinarians and advisors as well as customers.

Figure 18: Illustration of the Wikiporc/Sanibase system for quality assessment. The Sanibase name was changed to Wikiporc in 2008

Quality assurance

The Quality assurance (QA) systems in six European countries as well as China and South Africa were investigated in representative pork chains both at farm and chain level.

Northern and Western European countries are characterised by a main stream pork sector which has by far the largest market share. Companies are highly concentrated in all links of the pork supply chain, in particular the slaughterhouse and retail link. Chain coordination is increasingly facilitated by sector-wide private quality management standards such as QS (Qualität und Sicherheit) in Germany, IKB (Integrated Chain Management) in the Netherlands and Label Rouge in France. Sophisticated inter-company quality management and information systems also play an important role in the chain coordination. QA-systems in the main stream pork sector are well developed to differentiate pork production systems.

In most European countries there are also specialized pork chains aiming at niche or regional markets which distinguish themselves on pig breed, type of pork product (e.g. Ham of Bayonne in France, Jamon Iberico in Spain, or Mangalica pork in Hungary) or on quality management and organisation (such as Eichenhof chain in Germany or ''De Hoeve'' in The Netherlands).
It is expected that the concentration and differentiation processes in the European pork chains will continue. At the same time quality and animal welfare of convenience pork products in the main stream chains will increase alongside with further development of pork chains for niche markets.

The different regional chains are described in the book "European pork chains"

Quality management
The management of quality in a supply chain is of major importance to maintain profitability and requires coordination of activities across the whole supply chain. The following three concepts and approaches to support within chain coordination have been developed by Q-PorkChains:

1. A novel chain coordination model improving quality management strategies of European pork supply chains. The model has been developed to be applicable to a large diversity of pork supply chains and to support the definition and execution of chain oriented quality management structures and strategies. Chain coordination for quality management, strategic roles and responsibilities have been defined on three levels. The categories certification, coordination and control have been combined to characterize quality management actors. Coordination actors have been defined to coordinate quality management strategies: the "chain quality board" (normative level), the "network coordinator" (strategic

level) and the “quality broker” (operational level). The proposed innovative concept of a quality broker has been defined to facilitate the implementation of coordination mechanisms in pork supply chains. In addition, coordination mechanisms have been specified. The reference model can be used as a blueprint for companies when designing Quality Management Systems in collaboration with chain partners.

2. An information service model. The model has been defined to provide insights into existing gaps and supports the definition of flexible, cost and time saving hard and software solutions for actors in the supply chain. The information service model contains information supply models, information demand models, and gap models. These can be considered modular tools that help solving specific information and communication problems between buyers and suppliers in a chain. The reference models can be used as a blueprint for companies when analysing gaps and opportunities in information functions and in the design of improved information systems in collaboration with their chain partners.
3. An inter-enterprise quality management communication, coordination and collaboration approach. An approach of quality management responsibilities and governance has been developed that recognizes the coordination (governance) needs in different types of supply chains in the EU. The coordination needs are related to the risks involved in product and information exchanges between the different stages of a supply chain. These risks are possibilities for opportunistic behaviour of trading partners in the chain (e.g. last minute change to another buyer who offers a better price) and risks related to environmental uncertainties (e.g. related to weather circumstances).The models developed offer a support tool for company analysis when analysing or designing contracts with buyers and suppliers and how these are aligned with quality management systems in the chain.

4. Q-PORKCHAINS WEB-BASED PLATFORMS

Five web-based platforms were developed by Q-PorkChains.

1. Q-PorkChains public homepage (www.q-porkchains.org) is full of information and results from Q-PorkChains targeting all stakeholders within pig and pork production, as well as interested journalists and the general public. In addition, a comprehensive list of peer-reviewed articles and conference proceedings can be found at the homepage.

2. Open learning platform (www.porktraining.org) containing electronic learning resources for universities and industry within the pork sector have been established. The objective behind the learning platform is to supply teachers and trainers, as well as trainees with free, state-of-the-art learning resources. The learning resources can be used for non-commercial purposes such as teaching, learning and research. Q-PorkChains developed 10 learning resources within the areas; animal welfare and health, meat quality and safety, and sustainability and chain management. In total the platform contains 35 learning resources relevant for the pig and pork sector and there is the possibility to upload additional ones by external users of the learning platform.

3. QPC-models platform specifically targeted towards the pig and pork industry, farmers, slaughterhouses and meat processers. The models provide an overview of the consequences of selected pig production parameters with regard to various animal welfare, food safety and meat quality aspects. It is an interactive tool where the user can select and change relevant parameters and immediately get an overview of the consequences. The tool is based on models and meta-models developed in the Q-PorkChains project. Data and results of numerous scientific surveys are combined.
4. Product development toolbox (http://qpc-toolbox.org/), specifically targeting SME's in the European pork industry. The toolbox consists of different procedures and techniques for 1) opportunity identification, 2) idea generation, 3) idea screening, 4) concept testing, 5) product testing and 6) market testing. It is module based and guides the user through the whole product development process. The idea behind the product development toolbox is that especially actors without much experience in creative product development using this tool will be

able to conduct a more market oriented and less product oriented product development process and thereby increase their success rate.

5. Industry platform (www.q-porkchains-industry.org) realises knowledge exchange and dissemination specifically towards the industry. The aim of the Q-PorkChains Industry Platform is to inform stakeholders of the European pork industry about the innovative concepts of Q-PorkChains. Detailed descriptions of pilot chains and demonstration activities performed in Q-PorkChains can be found at this platform.

Q-PORKCHAINS 2007-2011

Q-PorkChains, within its course, described and clarified what characterises the successful European pork production sector throughout the interdependent and interlinked chain; from the living animal to processing and retailing.

Furthermore, the project's researchers developed very relevant and sophisticated models which reveal avenues for further optimisation. The models also pinpoint the conflicting interests within the complex system that the different actors are facing and the challenges they need to address.

Finally, researchers in close collaboration with the commercial partners developed numerous tools to help tackle the identified challenges and thus will allow the sector as a whole and actors individually, according to their respective strategies, to optimise their business and stay competitive.

Figure 19: The participants at the final Q-PorkChains conference at Mallorca

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SIXTH FRAMEWORK PROGRAMME

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