PORK SUPPLY CHAIN: A REVIEW

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ABSTRACT
The pork supply chain is a complex process, which involves multiple enterprises, and many associated factors that require coordination to deliver consumer value. This paper examines pork production and supply considering all processes, links and general issues involved in the chain. The methodology included a comprehensive literature review of 230 articles from refereed journals with the most relevant to links and general issues in the chain cited. A prominent theme was the need to meet the quality demands of the future, by understanding how all production chain links interact. This offers the prospect of identifying tools to control pork quality to fulfil market demands.

INTRODUCTION
The pork supply chain in the last decade has been the subject of extensive vertical integration or vertical coordination initiatives. The pork chain begins with breeders and finishes with final consumer. At production level horizontal collaboration is important to facilitate integration or coordination with abattoirs and retailers. Important attributes to develop these business links and manage the supply chain are commitment, communication and continuity (Hobbs, et al., 2000). Pork supply chain research has been based on several different perspectives (Klein et al., 1996) (Hobbs, Kerr & Klein, 1998) (Boger, et al., 2001).

For consumers, value consists of tangible and intangible attributes. Tangibles include flavour, texture, marbling (inter-muscular fat), nutritional content and price, and intangibles include food safety, animal welfare and environment. Articulation of these attributes and food chain participation is required for the food industry to competitively respond to the end customer (Fearne & Hughe, 1998). The contribution of this paper is to review this literature and summarize the key consumer and production issues as well as making suggestions for possible research areas in the future.

LINKS AND FACTORS IN THE PORK CHAIN
Delivery of pork at the right quality is the result of efficient coordination among many actors and links in the chain and their associated factors. This delivery process for pork and its links along the chain are shown in Figure 1. Below each link the main factors requiring coordination and which affect the quality of final product are represented. The generic factors identified are below the horizontal arrow in Figure 1.

Feeding
Pigs are mono-gastric animals and many dietary components are consequently readily transferred from the feed to the muscle and fat tissues, which subsequently affect pork quality (Katja, et al., 2003). Furthermore, it has been shown that muscle glycogen stores at the time of slaughter can be manipulated through feeding (Rosenvold et al., 2002) and thus influences the rate of pH decline and possibly the technological pork quality (pH is associated with stress which leads to poor eating quality). The objective is to reduce or overcome the problem of inferior meat quality associated with high pH24 h, commonly known as dark, firm and dry (DFD) meat.
Any feed components that either directly or indirectly reduce the stress responses may reduce stress-associated effects on pork quality. The immediate response to stress factors is the release of neurotransmitters in the brain, which stimulates the nervous system and releases stress hormones into the blood, which might stimulate muscle metabolism negatively in relation to subsequent pork quality (Katja, et al., 2003).

**Figure 1.** Links and key factors in the Pork Supply Chain

**Production**

Compared with modern production systems, the production systems of the past were very diversified depending on climate, soil, vegetative and productive characteristics of the husbandry areas, breeds reared, socio-economical environment, farming conditions and the technology employed. However, everincreasing competition has blurred these differences due to such factors as exchange of genetic material. Collaboration among countries and feeding management according to existing world-market prices, which together have resulted in more homogenous production systems and thus greater homogeneity in pork quality (Nardone & Valfre, 1999).

During the past decade consumers have become more concerned about such factors as ethical animal production, animal welfare, organic farming and sensory characteristics of the meat. Hence, extensive production, such as free-range or other forms of environmentally enriched production, and pigs fed natural feeds have become one of the new targets for European and North American pig meat industries (Lebret et al., 1998). A change from confined (housed) to freerange or other forms of environmentally enriched production systems may be a challenge for the future (Nilzen et al., 2001).
Haulage

Pre-slaughter handling includes mixing of unfamiliar animals, loading, transport and abattoir lairage. These handling practices can all induce stress (pigs in new groups fight to set the social hierarchy and become stressed) either psychologically or physically. Pre-slaughter stress is both an animal welfare issue and a quality issue, as it has long been recognised that pre-slaughter stress can adversely affect the quality of pork (Warriss et al. 1998a). Pre-slaughter stress can roughly be divided into long-term stress, such as on farm handling, mixing, loading and transport, and short-term stress, including lairage conditions and driving to the stunner. The two types of stress should not be considered as two separate things although long-term stress mainly leads to meat quality associated with that of DFD (Dark, Fort, Exudative) meat while short-term stress mainly leads to quality associated with PSE (Pale, Soft, Exudative) meat.

In several countries, 12–15 h pre-slaughter fasting is common practice to reduce the risk of microbial cross-contamination during slaughter. Furthermore, it is known that pigs should not be fed immediately prior to transport, because pigs with full guts show higher mortality during transport (Warris, 1998). Extended lairage does, however, raise other issues. The welfare of the pig may be compromised simply due to fasting as well as fighting in groups of mixed pigs. In addition, extended lairage decreases carcass yield (deadweight meat % compared to liveweight).

Mixing of unfamiliar animals should be avoided during pre-slaughter handling. Pigs in groups develop stable social hierarchies, which are disrupted when unfamiliar animals are mixed. This leads to skin laterations, which can be severe, and is a serious commercial problem as it decreases the value of the carcass (Faucitano, 2001). In addition, pigs that have fought show increased glycogen depletion in muscles and consequently high ultimate pH in the meat (Faucitano, 1998).

It is generally accepted that loading at the farm and off loading at the abattoir are the most stressful parts of transport (Barton-Gade, 1997). During transport the quality of the vehicle, ventilation, stocking densities and travel distances are of importance for the stress level induced in the pigs (Warriss et al., 1998a) (Faucitano, 2001)

Slaughterhouse

Slaughter immediately after delivery to the abattoir or after very short lairage may increase the proportion of PSE meat. On welfare grounds it is a legal requirement that all slaughter animals are rendered instantaneously insensible, and remain in this state until there is a complete loss of brain responsiveness due to exsanguination (Council Directive (93/119/CEE) 22 December 1993). The industry considers meat quality and the presence of haemorrhages and bone fractures when it evaluates the advantages and disadvantages of the different stunning systems. For pigs, the two most widely used stunning methods are carbon dioxide (CO2) and electrical stunning.

Despite much effort to determine the best stunning method from an ethical point of view, it is still a matter of dispute. (Bertram et al., 2002) showed that the CO2, electrical and captive bolt stunning are all associated with the introduction of physiological stress to different levels when compared with anaesthesia. The aim for the future must be to find stunning methods, which reduce physiological stress levels to those of anaesthesia. This would also improve such quality factors as WHC (Water Holding Capacity)
In terms of Slaughter procedure, chilling rate influences pork quality, as it depends on the pH/temperature history of the muscle (Bendall & Swatland, 1988). Several studies have investigated these effects. One problem that may arise with accelerated chilling is cold shortening, which can occur if the temperature decreases too rapidly, i.e. while the energy level in the muscle is still high.

On the other hand, accurate and objective prediction of pork carcass composition is crucial to the success of any carcass merit pricing system (Boland et al., 1995). Electromagnetic (EM) scanning has been reported to be an effective and reliable means for estimation of pork carcass composition because its multiple measurements determine the total lean content of the pork carcass. This information can be used to establish a component pricing system, allowing for payment of the actual lean value associated with ham, loin, and shoulder lean. (Huffman, 2002).

**Cutting line**

In the meat industry it is not only important that the carcass animal performance in terms of lean, but also in terms of the meat cuts conformation (meat to bone ratio) because it is a basic element for the pork supply chain integration. Carcass and meat classification allows firstly an effective control of the production system, and secondly facilitates the obtaining of meat with good conformation and following butchery the best performance. For that reason it has been incorporating in the market new technologies/tools which more accurately assess meat conformation of the carcass (e.g. ultrasonic scanning). This information has been used to improve the alignment of available product to destination markets (Gispert & Font, 2003).

For this cutting process evaluation of the technological quality of the meat is complex with multivariate properties, which is influenced by multiple interacting factors. These include breed, genotype, feeding, pre-slaughter handling, stunning, slaughter method, chilling and storage conditions. The quality attributes fat content, composition, uniformity and oxidative stability are mainly affected by genotype and feeding strategy, while water-holding capacity and colour are affected by almost all the above mentioned factors (Katja, et al., 2003)

**Processing**

As a consequence of market globalization, the production and manufacture of meat products is in a state of innovative flux. In order to keep or to reinforce their leading position, meat and food companies need to take into consideration the evolution of the purchasing and consumption habits of consumers, as well as the perception and actual trends of the consumers' demands. These consumers' demands are continuously changing, but some of the main parameters or axes are consolidating. Consumers demand high quality and convenient meat products, with natural flavour and taste, and very much appreciate the fresh appearance of minimally processed food. Besides, they require safe and natural products without additives such as preservatives and humectants (Wood et al., 2004).

Processing practices can be used to varying degrees to reduce variability and improve consistency of eating quality attributes of pork (Channon, et al., 2001).

With the increasing demand of convenient foods, the cooked meat market has grown steadily in recent years. Cooking is one of the most important factors that affect the quality of meat product due to a series of chemical and physical reactions, as cooking produces certain texture
and flavour and in the meantime, heating kills pathogen and keeps the food safe (Wood et al., 1995)

**Retail sector**
Consumers today are demanding an increasingly wide variety of foods, retail formats, and restaurant concepts. Food manufacturers, distributors, retailers, and foodservice operators face additional demands as they strive to profitably supply the large variety of goods and services on time and in the correct quantity. The task facing the food industry is neither easy nor cost-free. Some food firms are responding to the challenge by making innovative operational changes, reshaping how they work together with other members of the food supply chain and how they organize themselves as individual companies. Most notably, many food retailers are working more closely with distributors and manufacturers to best serve the consumer (Stewart & Martinez, 2002).

There is widespread agreement among many actors in the food sector that competitiveness on developed food markets is linked to the ability to develop new, differentiated products, which are able to exploit the fact that consumer preferences differ among consumer segments, increase consumer loyalty, and move competition away from the purely cost and price-based competition which characterises commodity-type markets. This is commonly accepted for food products with a higher degree of processing, but seems to an increasing extent also to characterise markets for fresh produce, including fresh vegetables, fresh fish and fresh meat (Verbeke et al. 2005).

Hog procurement practices are expected to continue to evolve toward tighter coordination systems to satisfy pork retailers and final consumers for consistently high-quality, safe pork products. More demanding consumers are encouraging more branded retail and food service products that entail both brand loyalty and product liability (Lawrence & Hayenga, 2000)

**Consumer**
Consumer and market orientation have been identified as the key factors for successful future development of today’s meat industries. An understanding of the factors that determine consumer perceptions of a product’s value or cost is of crucial importance to product innovation, choice of marketing strategy and maintenance of competitive advantage (Verbeke, 2000)

Consumers are confronted with different alternatives when they buy pork chops. Their decision-making process will be characterised by the use of information, evaluation of the available alternatives, development of a preference and finally making a choice, with a high probability of purchasing the prepreferred chop. The evaluation of alternatives is a complex phase and starts from desired evaluation criteria, which are also referred to as product characteristics or attributes (Verbeke et al., 2005). Attributes can be divided into intrinsic and extrinsic (Steenkamp, 1989). Intrinsic attributes are inextricably bound up with the core product, while extrinsic attributes are related to the product without being a part of it

Search attributes are available at the moment of shopping (e.g. colour, fat cover), while experience attributes can be evaluated only upon consumption (e.g. taste, tenderness). In addition, consumers can rely on “credence” attributes to assess meat quality. These attributes are of concern for the consumer but no intrinsic cues are directly accessible in the process of buying and consuming (e.g. organic, animal friendly) (Hugas, Garriga & Monfort 2002).
GENERAL FACTORS IN THE PORK CHAIN

Food safety
The harvest of livestock and the subsequent processing of raw meat products from livestock is a process that will consistently produce safe meat products for the consuming public provided the meat is handled safely and is properly cooked prior to consumption. However, history has shown that bacterial pathogens may evade even the best efforts to eliminate them by industry, government, and consumers. This may lead to adverse regulatory implications for the firm, or more importantly, may lead to foodborne illness in certain persons who may consume those products without a proper heat treatment prior to consumption. Bacterial reduction during the conversion of muscle to meat has always been an important challenge for the meat processing industry due to the impact on product safety and quality (Huffman 2002).

Cost and Legislation
The enterprises involved in the pork supply chain should consider the specific and general rules according to legislation to carry out the production. An efficient economic management through the chain is essential.

Economic relations
The traditional organization of the hog production slaughtering and processing system, characterized by independent producers and open market coordination with packers, is changing. The use of production and marketing contracts, weight/leaness premium and discount (P&D) pricing schedules, and vertical coordination figure are now pervasive in the sourcing and pricing of hogs (Poray et al., 2003).

Traceability
The outbreak of livestock-related diseases and their possible transfer to humans have underlined the necessity for a reliable system to trace an individual meat product back to its animal of origin. The meat industry is seeking to establish reassurance on traceability and production techniques that may help to promote confidence in the integrity and origin of their products. In the meat pork production the complex disassembly of the carcass into muscle groups, meat cuts and trimmings during conventional meat processing batch boning represents a "black hole" with respect to traceability of the animal of origin although batch traceability has been successfully achieved (Mousavi et al., 2002).

Environment
Stricter policy rules on environmental issues, changes in consumer attitudes towards the environmental effects of food production, and increasing regulations and competition regarding the quality and efficiency of production force agrifood industry to formulate management concepts and management systems which extend the traditional focus on economic efficiency to, firstly, incorporate quality assurance and quality improvement and secondly, reduce the use of natural resources and the negative impacts of production and trading activities on the environment (Schiefer, 2002)

CONCLUSIONS
Pork Supply chains are complex. The quality of final products is affected by a considerable number of processes and factors. This requires high levels of coordination among the chain's enterprises, with selective use of technical tools and processes to control pork quality to
satisfy market demands. To align production to consumer demands of the future a holistic analysis on pork chain is recommended to understand and coordinate properly the factors and links involved.

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