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Research Institutions and Authors

The following research institutions and author have contributed to this report

Prof. Dr. Albert Sundrum

Department of Animal Nutrition and Animal Health
Faculty of Organic Agricultural Sciences
University of Kassel
Nordbahnhofstr. 1a
D-37213 Witzenhausen
Germany

E-mail: Sundrum@wiz.uni-kassel.de
Internet: <http://uni-kassel.de/fb11cms/tierreg/>

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Quality production in organic, low-input and conventional pig production

1 Introduction

Considering the various aspects the issue of intrinsic and extrinsic pork quality is a very complex and multifactorial concept. It encompasses both objective carcass and organoleptic measures and subjective perceptions about the product and the production methods (Edwards & Casabianca, 1997). Beside the various factors influencing the different quality traits and their synergetic or antagonistic impacts the variability within the traits aggravates reasonable and valid conclusions from the previous data available. In the following, consumer perception and differences in framework conditions of pig production in relation to high- and low-input as well as organic production systems are described. Moreover, traits relevant for quality assessment, and main factors that affect traits of product and process quality are elucidated. Finally, potentials and disadvantages of different production systems in relation to the various quality traits are discussed. Due to the complexity of the production and growth process of pork the following paper can only consider the most relevant aspects between different systems and try to structure the rough lines, while the "fine tuning" remains the challenge of each farmer in his own individual farm system.

2 Perception of quality

It has been said that 'quality, like beauty, is in the eyes of the beholder'. Thus, quality has different meanings to different people, and the interests of one particular group may conflict with those of others. The attributes included in the concept of quality primarily depend on who is making the definition. Typical actors participating in the evaluation of food quality are food producers, government officials, marketing people and consumer groups.

In general, quality is assessed by the means of quantifiable traits that are more or less related to specific attributes of the product and the production process. Moreover, the assessment depends on the information delivered by sensory organs. The various information is filtered and evaluated by the brain depending on the specific information but also on the meaning concept that already exists in the cerebral cortex (Singer, 2000). A mental representation of a sensory event can shape neural processes that underlie the formulation of the actual sensory experience. Thus, the subjective sensory experience is shaped by interactions between expectations and incoming sensory information.

Sensory stimuli provide a high variability as does the discernment of sensory organs between the beholders, and the interpretation of the information by the cerebral cortex by the means of the existing meaning concept. Thus, there is a huge variability of quality pictures in the 'eyes of the beholder'. This makes it very difficult to deal with the quality issue in general and with the quality of pork in particular. Due to the comprehensive and subjective characteristics of quality it is reasonable to understand why scientists encounter difficulties when their research involves dealing with qualitative dimensions. On the other hand, the image of and the previous experience with the quality of specific food become more and more decisive in the purchase situation (Grunert et al., 2004). Process-related qualities of a food product are almost exclusively credence characteristics, since the consumer is seldom able to evaluate whether the food product has the promised process qualities. Thus, food image and reputation, whether based on facts or anecdotal, are increasingly important in food marketing. Currently, meat has a negative image in the public both due to food scandals of past years and the anecdotal statement that present day meat is fat and not proper from a nutritional viewpoint (Kubberod et al., 2002). In relation to fresh meat, some of the most crucial

quality characteristics demanded by the European society of today and tomorrow are outlined in Table 1.

Tab. 1. Demanded fresh meat characteristics (Andersen et al., 2005)

Trades	Individual Elements	Examples	Trades	Individual Elements	Examples
Safety	Pathogens Residues Contaminants	<i>Salmonella</i> Dioxin, PCB	Whole-someness	Welfare aspects Outdoor rearing Ethics	
Eating quality	Appearance Flavour Tenderness Juiciness		Convenience	Sustainability "Fresh and appealing" for days	Organic farming
Healthiness	Lean Lipid content/ composition Vitamins Minerals	PUFA,CLA Vitamin B, E Iron	Technological Quality	Water holding capacity (WHC) pH-value Protein content and its characteristics Lipid content and its characteristics Anti-oxidative status WHC	
Traceability Experiences	Origin History				
Diversity			Price		

Pork is the outcome of a very complex process. All the various characteristics of pork quality can not be assessed directly in each carcass because those measurements and assessments would be too expensive. Therefore, the previous scientific access for quality assessment of meat is primarily an indirect approach based on a few numbers of easily detectable quantitative traits and on the prescription of minimal standards in relation to the product in terms of size or composition and in relation to the production process. The prescriptions and the exclusion criteria vary between countries or between label programmes. The most encompassing prescriptions are enclosed in the EC-Regulation of organic livestock production (EEC No. 2092/91). Due to this approach extreme deviations in quality traits and deleterious effects are prevented. However, there is still space left within these framework conditions for a huge variability in pork quality.

Although it is the basis of scientific research work to deal with variation and its sources, the results of research work are mainly described and compared in terms of mean values supplemented with the information about whether specific factors have a significant impact or not. Most of the research studies carried out have focussed on individual factors in isolation and there are limited data in the literature on the interaction of a number of factors, particularly in relation to on-farm production practice. Consequently, the meaningfulness of previous results is often very limited and often does not allow one to draw general conclusions. As the relevance of the various factors change between different production systems it is a even more difficult to assess the ranking position of each factor within each production system in relation to the variation of product and process quality traits.

Taking the complexity of the production process and the variability of the product into consideration, the large gap between the huge variability in relation to product and process quality and the comparable low variability the consumer is aware of when buying pork becomes obvious. In the past, label programmes tried to meet the huge variability by establishing different production lines and thereby providing a higher differentiation between pork products. However, label programmes or food marketing in general put an emphasis on some very specific traits in the first

place while neglecting or ignoring others. Based merely on single traits to transform images to the consumer, food marketing ignores the existing and production related variability but tries to sell a more or less uniform image of the product. The market is full of simplifying and more or less wrong images and pictures which have found their way also into the eyes of the beholders and into their conceptual world, which makes it even more difficult to bring quality assessment more into line with reality.

3 Framework conditions of pig production

In pig production systems the use of external resources like bought-in feedstuffs and synthetic chemicals (mineral fertilizers, pesticides, synthetic amino acids, growth promoters etc.) has become standard practice. However, consumers and producers alike are becoming increasingly concerned about the level of chemicals used in conventional agriculture and are looking for options that reduce reliance on synthetic chemicals. As a result, interest in organic and low-input agriculture is growing steadily. Although there is a huge variation within the production methods, they are characterised by specific framework conditions and by the use of production tools. As pork consists to a high degree of protein, the protein source in the feeding rations is of high importance. The main aspects in relation to quality production are discussed below.

3.1 Conventional production systems

In conventional pig production, soybean meal is used world wide as the most important protein source. In addition, there are high value proteins from the food industry, such as brewers yeast, potato protein and maize gluten while grain legumes and extracted rape meal are used only in small quantities. In recent years, the use of synthetic amino acids has markedly increased as a tool to increase the supply of essential amino acids.

In general, genotypes used in conventional production are characterised by a high capacity for protein accretion. This is achieved by crossbreeding different strains, mostly belonging to the breeds Landrace, Large White, Duroc, and/or Hampshire. Additionally, boars of the Pietrain breed are used as sire due to their famous effect on lean meat percentage.

The structure of conventional pig production has developed to larger production units, which become increasingly specialised and produce more or less independently of the agricultural area. Moreover, a shift has taken place to centres of pig production in Denmark, Brittany in France, Flanders in Belgium, Lower Saxony and Westphalia in Germany as well as Catalonia in Spain and the eastern parts of the Po valley in Italy. However, from a global perspective pig production in Europe has to face the competition of the growing export-oriented, low-cost pork producing regions such as North-America, Brazil and potentially several Asian countries.

3.2 Low-input production systems

Low-input farming systems operate in between conventional and organic systems, trying on the one hand to minimize the use of external resources and synthetic tools and on the other hand to implement basic principles such as in organic systems. Due to a lack of a clear definition, low-input systems of husbandry methods are difficult to characterise. Especially kind and amount of inputs vary between farm units to a high degree. In comparison to industrialised systems, the use of bought-in feedstuffs, chemicals like growth promoters, prophylactic use of antibiotics etc. is reduced.

In recent years, a large number of label programmes has been developed which can be summarized under the topic of low-input systems. They often include some prescription in relation to housing methods, and with respect to the use of chemicals or bought-in feedstuffs.

In low-input systems a wide range of genotypes is used. While the production is mainly based on those types that are also used in conventional production some special breeds are used in label programmes. Iberian pig production in La Dehesa in Spain (Lopez-Bote, 1998), and Bisaro pig in Portugal (Santos e Silva et al., 2000) are examples of unconventional production systems with specific and highly demanded characteristics. These production systems have served as models to introduce new production systems, e.g. free-range systems. At present, only scarce knowledge is available regarding the influence of these systems on eating quality, and some of the data available often encounter eating quality problems rather than improvements (Jakobsen & Hermansen, 2001). Due to the huge variation within this production method, in the following it is done without especially referring to this production method.

3.3 Organic farming systems

Based on production guidelines, organic livestock farming has set itself the goal to establish an environmentally friendly production, to sustain animals in good health, to achieve high animal welfare standards, and to produce products of high quality. The idea and concept of organic livestock production was developed to provide an alternative to the progressive intensification in conventional animal production. The concept refers to the whole farm as the base and starting point of a comprehensive system. The realization of the system-oriented approach usually requires a complete re-organization of the farm, in which plant requirements have to be tailored to the concerns of animal husbandry and the extent and direction of animal husbandry adapted to home-grown feedstuffs. The aim is to achieve a sustainable production of animal products principally through precautionary and avoidance strategies.

While the energy supply does not provoke severe difficulties, the supply with essential amino acids is a challenge under the framework conditions of organic agriculture. Possibilities and limitations of protein supply in organic pig production have been recently reviewed (Sundrum et al., 2005). As soybean meal from conventional processing and synthetic amino acids are banned, grain legumes represent the main protein source. With respect to the maximum inclusion rate of home grown corn legumes, the availability and digestibility of essential amino acids, and type and quantity of anti-nutritive factors (ANF's) are most relevant. Moreover, the replacement of conventional by organically produced commercial feed (like soybean meal) comes to the fore in order to meet the protein requirements under organic conditions. In contrast to conventional production, determining factors for the use of feedstuffs are not only the price but in particular the availability of home-grown feedstuffs. Every farm has its own optimum with respect to marginal utility for the use of bought-in feedstuffs.

Concerning the genotypes used in organic farming they are often the same crossbreds as in conventional production but enclose also a wide range of rare breeds characterised by specific traits. Sometimes conservation of rare breeds is an objective in different farm units.

Depending on the prevalent conventional pig production systems, the organic systems vary between different European countries. In Spain, the traditional Dehesa systems have lend themselves to organic conversion fairly easily (Trujillo & Mata, 2000). Similarly in the UK, the prevalent outdoor breeding units have been relatively easy to convert to organic production, where farm size and crop rotations have allowed adequate space. In Western Europe and in Scandinavia, more intensive

systems have been converted to organic production by running the breeding stock outside during lactation and allowing pigs after weaning access to outdoor pens (Vermeer et al., 2000; Baumgartner et al., 2002). In Germany, organic pig production is primarily limited to small units where pigs are kept indoors with access to an open yard (Sundrum & Ebke, 2004), whereas outdoor fattening is rather the exception than the rule. In contrast, outdoor fattening have developed to a standard production method for organic pigs in Scandinavia (Jakobsen & Hermansen, 2001). In the year 2002 a number of 553,000 organic pigs have been estimated within the EU (Olmos & Lampkin, 2005). The major producing countries are Germany, Denmark, France and the UK. While total livestock numbers have increased in the following years, especially in the new member states, the number of pigs declined in most of the main pig production countries between 2002 and 2003 to a total number of about 472,000 pigs. Although increase and decline of demand for organic pork can not be extrapolated for the future, from the previous knowledge several challenges can be identified that have to be faced within organic pig production with regard to the future development.

3.4 Difference between organic and conventional livestock production

In organic livestock production the objectives of a land based system, the avoidance of specific means of production, and the priority of quality production rather than maximising production are of overriding importance. To deal with a limited availability of resources is therefore a main feature of organic production, while maximisation of protein accretion is of subordinate importance. Differences in priorities between conventional and organic livestock production and a comparison between the hierarchy related to the objectives are presented in table 2. With regard to the different objectives, different priorities, and different framework conditions, it has to be taken into consideration that organic and conventional livestock production belong to completely different farm systems. Therefore, the traditional approach which reduces agricultural problems to the level of single production traits is not directly comparable and compatible with the organic approach. General conclusions derived from conventional production systems are not directly compatible and therefore have not the same validity in organic livestock production.

Tab. 2. Differences in priorities between conventional and organic production system

Conventional	Organic
i. Minimizing production costs	i. System-oriented production, based on land use and use of organic feedstuffs
ii. Maximising productivity of farm animals	ii. Maximising efficiency within the whole farm system
iii. Maximizing performance (carcass yield, lean meat percentage)	iii. Optimising product and process quality (animal health and welfare, environmentally friendly production, naturalness)
iiii. Optimising single quality traits	iiii. Reducing production costs

4 Consumer perception

Consumers are interested in many aspects related to the quality of food, such as appearance, freshness, taste, nutritional value and food safety. Different consumers show different preferences and subjective perceptions in relation to the different features. People in different countries rank quality criteria differently. Price is an extremely visible attribute of pork related to quality by the notion of value. When purchasing pork products, customers try to assess the other quality

characteristics, i.e. the degree to which the need and expectations have been met in relation to the price given. A recent survey in Scotland indicates that price and product appearance are the primary meat selection criteria, the latter being used as a predictor of eating quality (McEachern & Schröder, 2002). Consumers are also becoming interested in foods produced according to ethical aspects of animal welfare principles and the aspect of environmental pollution. However, the main focus of interest is expected to vary to a high degree between groups and individuals.

Quality evaluation of fresh meat by consumers consists of two phases: i) previous to the actual purchase and ii) while eating the meat (Glitsch, 2000). Concerning the first stage, place of purchase and colour play a major role, while the price is considered to be less significant. After purchase flavour is one of the most significant quality characteristics.

According to Andersen (2000), appearance often has become the customer's single factor to evaluate the quality of pork. Consumers look for colour, and fluid retaining characteristics in the hope that those will indicate the potential eating quality. However, preferences of consumers vary to a high degree. While some groups of consumers exhibit greatest preference for DFD chops, others prefer normal appearing chops and a relevant number of consumers even show a preference for PSE chops (Jeremiah, 1994). Compared with highly marbled chops, leaner chops are darker and have a more acceptable appearance and are more likely to be purchased. However, they are also less tender, juicy, oily and flavoursome, indicating a disparity between purchase intent based on visual evaluation, and quality attributes of the cooked product (Brewer et al., 2001).

An increase in intramuscular fat (IMF) level is associated with an increase in visual perception of fat and a corresponding decrease in the willingness of consumers to purchase the meat, when expressed before testing (Fernandez et al., 1999). On the other hand, the perception of texture and taste was enhanced with an increased IMF level. The authors conclude that the positive effect of increased IMF holds true as long as it is not associated with an increase in the level of visible intermuscular fat. However, consumers also show a huge variability in their eating preference to non-visible IMF. In an hedonic test panel nearly one third of the consumers behaved indifferently towards an increase in IMF, for a minority preference of pork decreased with an increase in IMF while the majority preferred the pork with the highest IMF (Sundrum & Acosta Aragon, 2005).

Alternatively produced products have in common that their unique selling proposition is not directly visible to the consumer. Only additional information will identify the nature of the origin, or the production process of these foods (Ophuis, 1993). Within a sensory evaluation of 'free range pork' under different conditions of experience and awareness, labelling and prior experience with the product have an influence on the sensory evaluation of 'free range pork' favourably for a number of attributes. The author assumes that contextual elements are very important in the sensory evaluation of fresh foods.

A number of food scandals have stimulated consumer concerns about the safety and quality of food. Especially the 'convenience-driven' consumer segment is characterized by being concerned with meat quality and safety (Raewell, 1999) Sometimes the concept of animal welfare is mixed with items of food safety and sensory quality. Some consumers appear to delegate responsibility for ethical issues in meat production to the meat retailer or the government as consumers do not seem to wish to be reminded about issues connected with the animal when choosing meat (Bernués et al., 2003). Knowledge of production systems often appears of little consequence in terms of any pork market potentials as consumer groups often freely remark that there is no link between the negative images of production methods and their purchase behaviour (Ngapo et al., 2003). According to the

authors, consumer groups are clearly confused and mistrust the limited information available at the point of purchase.

According to Von Alvensleben (2003), consumers often are in a conflict situation where it is difficult for them to decide whether it is worth or they should be willing to pay a premium price for a premium product. In order to avoid dissonances and incoherencies when confronted with inconsistent information and uncertainty, consumers often ignore or suppress specific aspects that does not fit in their world view or justify their doubt in relation to the credibility of the information or deny being involved.

In several countries, first attempts to use the information obtained throughout the whole production chain have been tested in different marketing strategies to evoke positive associations with the product. The change from confinement to more free-range systems has been one of the tools to sell stories and improve marketing of meats. The promotion of such meat production systems has been based on anecdotal information rather than on real fact regarding the obtained overall quality (Andersen et al., 2005). Introduction of old breeds, which have not been exposed to genetic selection for decades, has become another tool to improve the image of meat (Santos e Silva et al., 2000; Hollo et al., 2003). This approach allows introduction of the term "original" showing potential in successful marketing of foods.

Introduction of the wholesomeness concept in the meat production, most often represented by organic production, is mainly due to a wish for re-establishing a positive meat sector image, e.g., meat safety and animal welfare aspects (Verbeke & Viaene, 2000). Consumers make a whole range of positive inferences from the label 'organic', and these refer not only to concern for the environment and health, but also to animal welfare and better taste (Bech-Larsen & Grunert, 1998; Bruhn, 2002). However, positive interferences do not necessarily lead to a purchase if consumers do not think that the trade-off between give and get components is sufficiently favourable.

5 Product quality

The modern use of "quality" raises problems: how to measure and evaluate quality, what is measured and which scale has to be used. It is commonly acknowledged that meat quality is a difficult characteristic to assess as many different aspects, both objective and subjective, make up the overall trait (Hofmann, 1994). Numerous literature is available describing single criteria of pork quality and those describing the production process. Without a fairly precise idea of what is measured and how the measurement is performed, a term such as "quality assurance" makes no sense (Andersen, 2000). The customers of fresh pork are both the meat-processing industry and consumers, who buy 65-80% and 20-35%, respectively, of the pork produced (Andersen, 2000). Currently, the market does not distinguish between technological qualities for processing and those for direct consumption. However, in the future there might be reasons to provide different pathways for technological and eating quality, which are therefore elucidated separately.

5.1 Technological quality

The term technological quality embraces all attributes relevant to the processing of fresh pork, including general meat processing and specific processing such as for catering.

Food safety. From the perspective of technological quality safety is the major issue, as control of safety during processing and distribution of meat products according to legislation calls for high safety demands. Additionally, safety refers to the shelf life of meat products.

Uniformity. The term uniformity includes muscle size, lean meat percentage, fat content of the carcass and pH-value or marbling pattern as characteristics of the meat composition. Uniformity is crucial especially in brand production (Branscheid & Claus, 1990) and becomes increasingly important as a consequence of the ongoing automation at the slaughter line and in the meat-processing industry. The objective to obtain meat cuts and products, which fit into the 'convenience-driven' consumer segment, give further rise to higher uniformity suitable for simple handling and preparation procedures.

Water-holding capacity (WHC). WHC includes the ability of the fresh pork to retain the water and bind extra water. The higher WHC, the more valuable the pork will be for use in highly processed products. Drip loss is an ongoing process involving the transfer of water from myofibrils to the extracellular space affected by structural features at several levels of organisation within muscle tissue (Bertram et al., 2002). The physical features of muscle that affect, or result from, fluid loss also influence pork colour. Increased extracellular fluid results in a pale product due to greater light reflectance and scatter. Many of the structural features of meat that affect colour and water-holding capacity are dictated by early post mortem events. According to Schäfer et al. (2002), early post mortem pH and temperature are sufficient to account for almost 90% of the variation in drip loss from pork. Markedly higher drip losses in pork with low pH-values occur especially after frozen storage (Person et al., 2005). Even though higher pH results in better WHC of pork, it also results in inferior colour, flavour and microbial stability of the product.

Lipid characteristics. If the lipid becomes too unsaturated, the meat is not suited for, e.g., sausage production. Furthermore, products become oxidative unstable which accelerate rancidity problems, especially in many preheated catering products with increased incidence of development in warmed-over-flavour. Therefore, the anti-oxidative status of pork, e.g. content of vitamin E, is an important technological quality criteria.

5.2 Eating quality

The image of fresh pork is to a high degree determined by its sensory quality (palatability, tenderness, juiciness) and its appearance (esp. colour, visible fat content and water holding capacity) at purchase in the shop (Schifferstein et al., 1988; Becker et al., 2000).

Appearance. Even though appearance does not have much to do with the eating quality of pork, it is becoming increasingly important in determining the consumer's purchase of pork. A bright red colour is perceived by consumers as indicative of freshness while consumers discriminate against meat that has turned brown in colour. The rate of discoloration in fresh meat is related to both the rate of pigment oxidation, oxygen consumption and the effectiveness of the metmyoglobin enzymatic reducing systems (Ledward, 1991). Moreover, the drip loss and the visible fat play an important role with regard to the attractiveness.

Tenderness. The contractile state of the muscle after rigor mortis is a major factor in meat tenderness, which is affected by the post mortem conditions creating differences in tenderness. Ageing of fresh pork can be used to improve tenderness. The process is based on a continuous weakening of the structural elements by different endogenous muscle peptidases along with an improved palatability (Taylor et al., 1995).

Juiciness. Juiciness of pork is associated with the amount of moisture present in the cooked product and the amount of intramuscular fat (IMF). Increase in ultimate pH of the pork is associated with increased moisture retention in the heated product. In contrast, low pH after slaughter, which gives rise to pale, soft and exudative (PSE) pork, is closely related with low moisture content of cooked

pork. Also the distribution of water within muscles and the WHC affect juiciness and tenderness (Offer & Knight, 1988).

Meat flavour. Meat flavour represents a large number of compounds formed during heating of the product. The flavour development mainly depends on constituents in the fresh meat, e.g. fat composition, peptides, glycogen concentration, vitamin content, and the heat treatment of the product. Increasing temperatures increase flavour development. According to Andersen (2000), the intensity of pork flavour has decreased during recent years, most probably as a result of the production of pork with a minimal content of intramuscular fat.

Intramuscular fat (IMF). The importance of the IMF content has been defined by many authors as flavour carrier (Schwörer and Morel, 1987; Affentranger et al., 1996). Only the finely distributed fat in the muscle, recognizable in higher contents as marbling, makes a taste differentiation between animal varieties possible whereas low-fat muscle meat is almost taste-neutral. Moreover, IMF is decisive in relation to the capacity to maintain juiciness, and, when cooked, by tenderness, and a typical aroma (Fischer, 2001). While the IMF optimal for taste is between 2.5% and 3% (Fernandez et al., 1999), modern slaughter pigs currently show an average IMF content of only 1% (Köhler et al., 1999). Higher pH-value and lipid content tend to decrease mechanical resistance and hardness of meat (Monin et al., 1999). According to Warkup & Kempster (1991) a combination of high growth rate and high IMF is beneficial to eating quality where as low growth rate and low IMF produce tougher, and drier meat.

5.3 Factors affecting pork quality

Factors of significance for pork quality have been in the focus of pig science for decades. However, most of the present knowledge is based on studies investigating the influence of a single or at the most two factors. However, there are limited data in the literature concerning the understanding of how production and slaughter factors interact in relation to pork quality, particularly in relation to on-farm production practices (Rosenvold et al., 2003). In the following, the most relevant factors are outlined.

Genetics. Genetics are known to have a marked influence on both production and quality traits. The capacity for protein accretion is determined principally by the genotype. However, the dominant effect of the first-limiting AA for protein accretion cannot be affected by the properties of the animals (Susenbeth et al., 1999). Through breeding for high meat content and low feed expenditure, the extent of the utilization of AAs for the protein accretion has not changed (Susenbeth, 2002). Thus, the superiority of animals with a high genetic capacity for protein accretion becomes manifest only in combination with a corresponding protein supply.

Numerous reports on the development of pale, soft and exudative (PSE) pork have focused on major gene effects. Advances in the understanding of calcium release from the sarcoplasmic channel led to the discovery of alterations in amino acid sequence (HAL-1843 mutation) in the calcium release channel protein, also called the ryanodine receptor (RYR1; Fujii et al., 1991). The n allele of the HAL gene affects numerous pork texture traits in a way that can be considered as detrimental to acceptance (Monin et al., 1999). The meat is less rough, more cohesive, harder, more fibrous, less granular, more elastic, and less easy to swallow. Also the mechanical resistance for raw and cooked meat is higher.

The Napole gene is another genetic abnormality that can lead to inferior pork quality. The dominant RN- allele results in higher than normal muscle glycogen stores and in extended post mortem pH decline that leads to pork with a lower than normal ultimate meat pH, reduced water-holding

capacity, and greater cooking losses (Fernandez et al., 1992; LeRoy et al., 1999; Jonsäll et al., 2001). Monin and Sellier (1985) referred to this condition as the Hampshire effect, due to its prevalence in the Hampshire breed.

Despite an abundance of research describing PSE pork characteristics, and a reduction in the frequency of major genes with known deleterious effects on pork quality, Cassens (2000) concluded that little progress has been made in reducing the incidence of PSE pork. This highlights the complexity of the PSE pork problem, which is not only restricted to the alleles of genes involved. Murray and Johnson (1998) reported that in a population of more than thousand pigs, 90% of the PSE condition was caused by factors other than the HAL-1843 gene. Oeckel et al. (2001) conclude from the results of a consumer panel that the elimination of the HAL gene from the pig population does not guarantee a better palatability of pork. If the main gene defects (HAL and RN genes) can be excluded, genetics, in the view of De Vries et al. (2000) and Tribout & Bidanel (2000), contributes only with a proportion of less than 30% to the total variation of meat quality criteria.

With the exception of the above mentioned major genes, the heritability of most attributes referring to the quality of pork is low, except for that of intramuscular fat content (IMF) (reviewed by Rosenvold et al., 2003). Increased IMF is associated with improved eating quality. Although the heritability of IMF and fat tissue is high, the genetic correlation between them is very low (Wood, 1990), which suggests that selection for high IMF in lean carcasses should be possible. However, increase of IMF requires incorporating generally fatter breeds (e.g. DU) and is expected to lead to decreased income due to poorer grading (Glodek, 1996). On the other hand, a successful implementation of a breeding programme focussing on IMF content in pork has been reported from Switzerland (Schwörer et al., 2000).

In the past, there has been considerable interest in the use of genotypes (esp. Duroc) with high levels of IMF in an attempt to improve eating quality. There have been various evaluations of the influence of the Duroc breed on eating quality with variable results. While several studies have found no significant advantage for the Duroc breed for eating quality (McGloughlin et al., 1988; Martel et al., 1998; Edwards et al., 1992), other studies highlight the benefit of this breed in several but not all quality traits (MLC, 1992; Ellis et al., 1996; Sundrum & Acosta Aragon, 2005). However, within the current carcass grading and payment system final products of stress resistant sire lines or those producing a high IMF content (e.g. DU) are not favoured because of higher back-fat and lower lean meat (Glodek, 1996; Laube, 2000). Thus, products with a high pork quality have the lowest market price.

Sex. The difference in sensory quality between females and castrated males is not consistent over several studies. Enfält et al. (1997) and Jonsäll et al. (2001) found that loins from castrated males scored higher for tenderness and juiciness than loins from females. In contrast, Jonsäll et al. (2000) found no sensory effect of sex on loins, and the same working group detected in a further investigation that loin from gilts scored higher for juiciness and lower for off-flavour than loin from castrated males. Obviously, the effect of sex on sensorial quality is of minor relevance and can be overruled by other effects.

Feeding strategies. Pig producers mainly try to approach maximal rates of lean tissue deposition and carcass index values by means of providing diets formulated to meet all of the known requirements. In the growing period, protein accretion increases as the supply of limiting amino acids increases (Heger et al., 2002). The dose-effect ratio can be subdivided into the nutrition-dependent phase, which is substantially linear, and the plateau phase, which is independent of nutrition supply and

whose maximum depends on features of the animals, primarily characterised by the genotype (Susenbeth, 2002).

Feeding is an important tool as many dietary components are readily transferred from the feed to the fat tissues. Thus, the fatty acid (Wood & Enser, 1997) and vitamin composition (e.g. vitamin E) in the diet (Buckley et al., 1995) has a direct influence on the quality of the meat. Extensive experimental evidence exists for feed induced optimisation of the fatty acid profile, i.e., optimal ratio between saturated, monounsaturated and polyunsaturated fatty acids, to meet the dietary recommendations for humans in their intake of pork (Jakobsen, 1999). The large amount of unsaturated fatty acids are responsible for softer back-fat observed with pigs fed corresponding feedstuffs. The "softness" of pork can be a problem for further processing (e.g., sausage production), especially when pigs have been fed too high a content of polyunsaturated fatty acids (Jorgensen et al., 1996; Warnants et al., 1998).

Increased awareness by consumers of the link between an increased intake of omega-3 fatty acids, and a reduction in the risk for cardiovascular disease, has led to an increased demand for products with a higher content of these unsaturated fatty acids. Leskanich et al. (1997) increased the omega-3 fatty acid content of pig fat, without effects on the sensory attributes of the meat by feeding 2% rapeseed oil and 1% fish oil to pigs during the finishing phase. However, increasing the content of these fatty acids in the pig feed can lead to a problem with rancidity, as the unsaturated fatty acids become oxidized. Sensory analysis data have provided evidence of a higher detection rate of off-flavours in processed pork derived from pigs fed diets containing low-erucic acid rapeseed oil, due to the presence of oxidation products of linolenic acid (Wood & Enser, 1997).

Oxidatively stable raw materials are necessary to obtain a profitable shelf life of the products (Sheard et al., 2000). When fed above requirement levels, vitamin E increases the oxidative stability in fresh pork and pork products considerably (Jensen et al., 1998). Selenium is also involved in reducing lipid oxidation; there is no evidence, however, that supplying additional selenium above the requirements improves pork quality (NRC, 1998).

By feeding diets containing the optimal protein:energy ratio, an increase of protein accretion together with a reduction in carcass fat content can be realized. Several authors highlight that the limit of leanness that will still allow one to market a palatable commodity has already been exceeded to a high degree (Honikel, 1996; Fischer, 2001). The negative selection in the back-fat thickness of the animals decreased considerably the intramuscular fat (IMF) content of the meat (Rosner et al., 2003).

According to Essen-Gustavsson et al. (1994), Castell et al. (1994) and Sundrum et al. (2000) the IMF content in the M.l.d. can be clearly increased by a longer ratio energy: crude protein (lysine) content in the diet without increasing fat area and back-fat thickness. Nutritional effects on intramuscular fat characteristics and content are clearly greater than genetic effects (Cameron et al., 2000; Sundrum & Acosta Aragon, 2005). Furthermore, an increase of 30 days in the age of pigs slaughtered at 110 kg body weight greatly influences the carcass and the muscle chemical composition, including the IMF in *M. longissimus* (Lebret et al., 2001).

In organic pig production, all animals must have access to roughages, primarily for welfare reasons. Increase of bacterially fermentable substances (BFS), enriched with roughage, reduces growth, protein retention and feed conversion efficiency (Kreuzer et al., 1999). Furthermore, carcass yield is reduced with increasing BFS content of feed. Pigs with an access to roughage, and fed restrictively with a concentrate diet showed increased lean meat percentage and a decreased tenderness while other eating quality attributes remained unchanged (Sather et al., 1997; Danielsen et al., 2000).

Fatty acid composition of pork from free-range pigs with access to roughage has been reported to be more unsaturated compared to conventional production (Hansen et al., 2000; Nilzén et al., 2001). Moreover, recent studies showed that feeding with lupines has the potential to reduce the amount of skatole in back-fat of pigs (Hansen & Magnussen, 2004).

Muscle glycogen stores have been recognised to be decisive for meat quality. Muscle glycogen stores at the time of slaughter can be manipulated through feeding (Rosenvold et al., 2001, 2002) and thus influence the rate of pH decline and possibly the technological pork quality.

Housing methods and management practice. Standardized production systems are of high priority for the modern pig industry, which is based on slaughter lines with rapid carcass flow and produces meat of known quality (high uniformity) compared to many of the alternative management systems or niche productions, which are emerging due to customer demands. The intermediary mechanism between animal welfare, effect of stress and impaired organoleptic meat quality is situated at the level of the muscle cell metabolism. The more anaerobic metabolism can be avoided, the less risk for a deteriorated meat quality. Hence, risk factors impairing ethical and organoleptic features of fresh pork are really overlapping. However, studies comparing indoor and outdoor fattening are inconsistent. According to Edwards & Casabianca (1997) measures of carcass and meat quality have generally failed to demonstrate any superiority of products from outdoors. Several studies even showed a disadvantage of outdoor production in relation to the eating quality of pork compared to indoor production. In investigation of Entfält et al. (1997) and Jonsäll et al. (2000) loins from pigs reared outdoors were less juicy and had a lower intensity of acidulous taste than loins from pigs reared indoors. In contrast, Jonsäll et al. (2002), Stern et al. (2003), and Gentry et al. (2004) could find no differences in pork eating qualities of outdoor reared pigs compared to intensive rearing. According to Beattie et al. (2000) pigs from enriched environments produced pork with greater tenderness than pigs fattened in barren environments.

Animal health. It is well known that diseases in fattening pigs can lead to a considerable reduction in growth performance. Respiratory diseases cause the highest economic losses due to reduced growth, and higher production costs including costs for veterinarians and remedies (Miller & Dorn, 1990, Hammel & Blaha, 1993). Impacts of animal diseases on quantitative carcass traits generally seem to be of minor importance (Doedt, 1997), and can even improve the evaluation by carcass grading because of a reduced fat and an increased lean meat content (Wittmann et al., 1995). Concerning the impact of diseases on meat quality traits, the literature provides inconsistent results. While some investigators found a higher incidence of PSE-meat in the carcass of pigs with respiratory diseases (Hammel & Blaha, 1993; Doedt, 1997), others did not find such a relationship (Wittmann et al., 1995) or even assessed a reduced incidence of 'PSE-meat' while the incidence of 'DFD-meat' clearly increased (Schütte et al., 1996). Obviously, the implications on quality traits vary between animals and between farms. They are not only related to the extent of the stress factor itself but are modified to a high degree by the specific physiological status and the specific circumstances. In general, pathological findings in the plucks of pigs are not the exception. They are often found to a high degree in pigs assessed at the abattoir (Doedt, 1997; Bostelmann, 2000; Sundrum & Ebke, 2004), indicating a serious need for action.

Procedures around slaughter and post mortem. Pre-slaughter handling includes removal from the home-cage, transport, mixing of unfamiliar pigs, loading, and abattoir lairage. These handling practices can all induce stress due to exposure to novel environments, interactions with humans and aggressive interactions with co specific. Pre-slaughter stress is both an animal welfare issue and it can adversely affect the quality of pork (Warriss et al., 1998). Animals that have fought during pre-

slaughter handling show glycogen depletion in muscles leading to a progressively higher ultimate pH in the meat, which results in an increase in the incidence of DFD meat (Faucitano, 1998; Warriss et al., 1998). Prolonged transport of pigs (8 h versus 0.5 h) has been found to improve tenderness due to reduced glycolytic potential at the time of slaughter and subsequent higher ultimate pH (Leheska et al., 2003). Van der Wal et al. (1997) found that 3 to 4 h resting period before slaughter was optimal with respect to pork quality. Short-term stress immediately prior to stunning is shown to result in lower pH-values and higher temperatures early post mortem (van der Wal et al., 1997, 1999; Stoier et al., 2001), which is generally accepted to reduce the WHC of pork. Finally, CO₂-stunning of pigs should be recommended when the aim is superior WHC, as it is generally accepted that this results in higher WHC compared with electrical stunning (Channon et al., 2002).

5.4 Relationships between quantitative and qualitative traits

A literature review shows that a large number of traits (including terminal sire genotype, sex, slaughter weight, feeding and housing regime and slaughter-house) have been found to have a more or less clear effect on carcass and meat quality in pigs and on the organoleptic properties of fresh pork. The fact that relatively few significant interactions for eating quality traits have been found in multi-factorial experiments (Ellis et al., 1996; Sundrum & Acosta Aragon, 2005), it can be assumed that the effects of most of the factors are likely to be additive. There is reason to assume that the degree of influence is not only due to the factor itself but is very much depending on the system context (context-variant), in which they are at work.

For a high variation in growth rate as well as in protein and fat accretion differences in living conditions, environmental temperature (Bellego et al., 2002), stocking rate (Edmonds et al., 1998) and in the general stress situations (Whittemore et al., 1988; Schinckel, 1994; Hyun et al., 1998a; 1998b) are held responsible. In on-farm investigation, Elbers et al. (1989) found for example a considerable variation in the digestibility of organic matter (77-84%). The variation between the farms was greater than within the farms.

Although uniformity is often emphasized to be of high importance for the pork industry, only few in the pork industry and in the primary production of pigs have realised or cared about the huge variations for most quality traits (Andersen, 2000). Trade value of carcasses is determined principally by the lean meat proportion, slaughter weight and cuts composition on the basis of price labels. In responding to market pressures improved nutritional practices in combination with genetic selection has improved the leanness of pork considerably. With an increase of lean meat and an extreme reduction of overlay fat, the risk that meat deficiencies will appear increases (Harr, 1989; Lengerken, 1990). Meat research experts have been demanding for years that a muscle meat proportion of 55%, for reasons of meat quality, should not be exceeded (Schepper et al., 1983; Honikel, 1996; Fischer, 2001).

Lean meat percentage and IMF content are correlated negatively (Köhler et al., 1999; Baulain et al., 2000; Sundrum et al., 2000). With a corresponding inclusion of the IMF in the breeding strategy, the meat proportion will consequently be reduced. Because breeding for high meat proportion in pigs leads to an increased formation of 'white fibres', extremely hypertrophied muscles are not only almost fat-free, but strikingly light. Pigs with a high lean meat proportion produce more 'PSE meat' (Doedt, 1997). In addition, a high proportion of ham in relation to the total carcass is negatively correlated with the appearance of 'PSE meat' as a consequence of the related muscle hypertrophy

(Fewson et al., 1987; Kallweit, 1989). A consideration of the ham form in the payment system thus leads to an increase of meat condition deficiencies (Doedt, 1997).

One-sided breeding for rapid growth and meat quantity performance makes osteochondrosis and stress myopathies in pigs more likely (Claus, 1996; Bickardt, 1998). The accelerated protein accretion puts a strain on a young immature skeleton. The illness is determined by cartilage degeneration with epiphyseolyses and bone proliferative reactions. Pigs with high lean meat percentage and high growth rates showed poor assessment values in respect of carpal and tarsal joints (Lundeheim, 1987; Huang et al., 1995). According to Rauw et al. (1998), the characteristics antagonism between growth intensity and health impairment give rise to the supposition that the domestication of pigs has led to reduced ability to deal with environmentally determined stress.

6 Animal welfare issue

An increasing number of consumers accept good living conditions, appropriate to the needs of the animals, as a 'process quality', which even justifies premium prices for animal products (Badertscher-Fawaz et al., 1998; Verbeke & Viane, 2000). There is a greater potential for optimal welfare in organic systems compared to intensive systems (Barton Gade, 2002). However, the realisation of minimal standards can not be treated as equivalent to appropriate livestock housing conditions and high animal health and welfare status (Sundrum, 1999). Minimal standards are primarily based on political decisions and a compromise between different interests that are not in all cases related directly to the animal welfare issue. The appropriateness of minimal standards can not be judged by an absolute 'yes or no' decision, but requires a comparative assessment, ranking on a scale between very good and very poor. Furthermore, minimal standards do not include all relevant aspects of animal welfare. Thus, minimal standards represent only a small section of the interrelationship between farm animals and their living conditions. Beside the housing conditions, the quality of stockman-ship and management, the feeding, climatic factors or the hygienic situation have essential influence on animal health and welfare (Bergsten & Pettersson, 1992; Rushen & Passillé, 1992; Thielen & Kienzle, 1994). Those factors are not part of the Council Directives or the EEC-Regulation due to the difficulties in quantification and to the variation in time.

7 Environmental impacts

The complex interactions between the different groups of substances, the constantly varying environment in which animals are reared, and the considerable fluctuation found in the quantities of substances in circulation mean that any quantification of the emissions emanating from pig production must of necessity be only very approximate. Any assessment of the efficiency of individual measures or specific rearing systems can only be of limited scope, and the resulting data can scarcely be considered valid, if the farm context is left out of consideration (Sundrum, 2002). In pig husbandry there are four principal strategies of feeding measures to reduce nutrient losses (Flachowsky, 1993; Canh et al., 1998):

- reduction of the protein content in the feed ration and thus the N input per animal through a corresponding choice of protein carriers, differentiated feeding according to living mass and performance (phase feeding) and supplementing with industrial amino-acids,
- increase of the animals' performance because the N emissions will thereby be lowered in terms of kg per growth increase or per piglet, if the farm conditions remain equal,
- displacement of nitrogen emission from the urine into excrement by raising the biologically fermentable substance in the ration of nitrogen in the hind gut through microbes.

- reduction of the pH-value in the urine and in faeces and therewith reduce the pH-value in the slurry by a targeted selection of feed components.

Reduction in nitrogen excretion is often set equal with a reduction in nitrogen emission. This is only true in those cases where the excess nitrogen in the commercial fertilizer can be caught and retained in the agricultural nutrient cycle. If the nutrients are, however, discharged from the cycle and emitted into the environment, this can mean correspondingly high environmental damage. A reduction of N input per animal is possible, especially by means of multi-phase feeding. The greater the use of nutrient-graduated feed mixtures, the higher the reduction potential with regard to nitrogen excretion. Substantial savings can thus be achieved if the phase feeding is accompanied by a simultaneous reduction of protein content (Kaiser et al., 1998).

In organic animal husbandry the possibilities for the adaptation of the feed ration to the specific requirements by means of principal use of self-produced feed and avoiding synthetic amino acids are considerably limited (Sundrum, 2002). However, the organic farmer has other possibilities and strategies to reduce nutrient emissions. The main specifications concerning environmentally friendly production have to do with the renunciation of pesticides and mineral nitrogen, with the need to reduce the number of farm animals per area unit and the handicap to minimise the amount of bought-in feedstuffs. Without these substitutes, organic farming must rely on efficient nutrient circulation within the farm to maintain soil fertility and high production. Reduction of pollution or energy consumption is reached by a systemic and casually related approach, while conventional strategies are often based on technical and management related measures (Kristensen & Halberg, 1997). Model calculations of Hermansen & Kristensen (1998) showed that mixed farm systems including cattle and pigs, as intended in organic agriculture, provide a potential for a clear higher nutrient efficiency and an improved balance sheet compared to specialised farms because interactions between plant cultivation and livestock production can be better optimised.

8. Constraints and potentials for quality production

The scientific knowledge on how to produce pork of a high intrinsic and extrinsic quality has markedly increased during the last decades. On the other hand, it is obvious that knowledge alone is not sufficient to change the current unsatisfactory situation and implement an encompassing strategy to improve pork quality. The production of pork takes place within specific framework conditions characterised mainly by the availability of resources (nutrients, housing conditions, investments, labour time, management skills etc.) and by the potentials to gain a high price on the market. As described above framework conditions differ markedly between production systems. With regard to quality production each production system has to face specific constraints. Some aspects in relation to the different production systems are discussed below without claiming to be exhaustive.

8.1. Conventional production systems

A main objective in conventional pig production is to minimize production costs and to maximize those results that are directly rewarded by the market. The main factors that affect productions costs are prices for feed, young stock, and building. Furthermore, carcass yield, feed conversion, and the economic gain per kg pork have a high impact on the gross margin. Under the current framework conditions carcass with the highest lean meat gains the highest price. At the same time it is the most efficient strategy to reduce production costs as increase in protein accretion goes along with an increase in daily weight gain and an improvement in feed conversion (Susenbeth, 2002).

Furthermore, a high lean meat provides the highest yield and profit for the processing industry. Due to the antagonistic relationships between quantitative and qualitative traits, the current payment system is in contradiction to the production of pork with a high eating quality and does not even consequently prevent all negative side-effects on technological quality traits. For example, although an enormous amount of research has been directed at the PSE problem, and the basis for and understanding of the syndrome is in hand, little progress in eliminating or minimizing the problem is recorded (Cassens, 2000). The author conclude that the reason for the little progress is due to the marketing-system which does not reward quality with a premium, but rather pays for quantity. Moreover, the farmers are punished by deductions if they do not fulfil the quantitative demands of the meat industry.

Focussing primarily on quantitative traits and on a reduction in production costs there is only little space for improvements with respect to quality features. Those are strived for in the first place by breeding techniques. However, breeding efforts to improve quality traits within the current framework conditions are limited due to antagonistic relationships between quantitative and qualitative traits. Moreover, also limitations concerning quantitative traits become obvious. Thus, the genetic capacity for growth rate and lean meat gain has improved at a faster rate than achieved in practice. According to Boyd et al. (2000) the biggest constraint on the expression of growth potential appears not to be nutrition but immune stress and clinical and sub-clinical disease. Pigs that are capable of gaining 850-900 g/d in a good commercial environment often fail to achieve more than 700-750 g/d in many operations (Schinckel & De Lange, 1996; Holck et al., 1997). Subclinical disease and immune challenge are generally associated with lower feed intake (reviewed by Johnson, 1997), while simultaneously the amino acid needs of challenged animals increases (Williams, 1998). Anabolic processes are interrupted and coincident catabolic processes are amplified (Spurlock, 1997). The net effect is a marked reduction in growth as the body places priority on defending against challenge. Any attempt to over-ride the process through greater nutrient density seems to be futile.

Intensive pig production systems have shown severe negative impacts on animal health and welfare (reviewed by Borell et al., 1997; Rauw et al., 1998). Further constraints of intensive production are expected due to the dramatic effects on environmental pollution caused by a high nutrient input and nutrient loss per land area (Monteny & Voermans, 1998; Van den Weghe, 1999). As if the limitations of the conventional approach in relation to quality production are not difficult enough, pig production in Europe is confronted with the challenge of an open global world market. There is reason to assume that the present relatively cost-intensive pork production in EU-countries has to face increasing challenges to compete with the increasing export oriented and low cost pork production in countries like Brazil, or China. Currently, there seems to be no preparedness for the upcoming subsidy-free global market.

8.2 Low-input production systems

Pork production in low-input systems is highly diversified as the term low-input is not clearly defined. Generally, the low-input is related to nutrients and chemicals. Because of production conditions that differ from the conventional production, products are often offered as brand products. Those systems included traditional southern European label products (e.g. 'Pata negra') a cured product of high economic value from very extensive husbandry practices where genotype-environment interactions result in measurable effects to pork quality (Lopez-Bote, 1998). Also pork from meat label programmes have shown to produce meat of higher quality compared to those

without a label programme (Bostelmann, 2000). Obviously, the specific guidelines of meat label programmes in relation to breeding, transport and handling before slaughter is able to provide a positive influence on pork quality. On the other hand, pork from free range systems show inconsistent results in relation to eating quality (Entfält et al., 1997; Jonsäll et al., 2002; Gentry et al., 2004). In label programmes single traits are often put into focus and highlighted towards a specific consumer clientele while other traits are not different from conventional production. However, there is widespread evidence that consumers overestimate the predictiveness of such characteristics (Grunert et al., 2004).

Due to the various impact factors the variation in the level of quality traits is expected to be huge both between low-input systems and between production units. Therefore, conclusions in relation to limitations and potentials for quality production are difficult to draw and can not be generalised but need clarifying in each production system.

The consumers' intrinsic desire for variety is recognized as an important characteristic that influences consumers' food choice behaviour and will become an ever-increasing factor in future food marketing due to the increasing allowances for food consumption in most industrialized countries (Thiele & Weiss, 2003). Consequently, consumers' demand for food diversity might be one of the driving forces in the development of new concepts for fresh meat production in brand label programmes, i.e., meats that differ in quality attributes, using all the possible quality control tools from conception to consumption.

8.3 Organic production systems

Organic pig production is clearly demarcated from the conventional production by the EEC-Regulation on organic agriculture as the basic standard. However, the production conditions vary from outdoor pig production to indoor production and encompass huge differences between regions and seasons not only in relation to environmental conditions but especially in relation to nutrient supply and genotype. While in conventional production external resources e.g. high quality protein in the feed ration are used to a high degree and only suboptimal living conditions for the animals are provided, the organic approach is restricted to the use of feed materials of organic origin while on the other hand providing good living conditions for the animals. The holistic approach of organic farming is in line with the growing wish for improved traceability by the consumers, including the ever-rising consumer concern in relation to the introduction of genetically modified organisms in the feed and food production.

Due to the far-reaching renunciation of external nutrient resources organic pig production can claim to be environmentally friendly as a low input of nutrients results in low nutrient losses (Sundrum, 2002). Furthermore, the prescriptions concerning housing conditions and husbandry practice provide good conditions for the animal welfare issue. However, the framework conditions are not equivalent to a high animal health status (Sundrum, 1999). There is reason to assume that additional efforts have to be implemented to ensure a high health status and to ensure food safety. To manage a farm as a comprehensive system is a great challenge and requires high qualified management skills. The mixed farm system, strived for in organic farming is in contradiction to the specialisation in conventional farms and aggravates to meet the demands of a high quality production because of the widespread issues that have to be dealt with.

Due to the restricted availability of limited amino acids in organic livestock production protein accretion capacity is limited. To optimise the use of limited resources, the farmer is challenged to adapt the level of amino acid supply to the protein accretion capacity of the animals to a high degree

as suboptimal supply reduces the performance while excess supply with amino acids cannot further increase performance. Different measures are at the farmer's disposal to optimise the use of limiting resources and to adapt the supply of limiting amino acids to the growth process in the various stages (Millet et al., 2004; Sundrum et al., 2005). However, those measures are mainly characterised by increased efforts, for example in terms of time input and expenditures. Thus, organic farmers are in no way competitive with the productivity and the production costs in conventional livestock production (Kempkens, 2003).

When organic pork is offered, those choosing the organic variety expect it to be of better quality across all quality dimensions, including taste and tenderness. However, the quality experienced after preparing and eating organic pork provide varying results and often fell short of expectations (Grunert & Andersen, 2000; Jonsäll et al., 2002; Olsson et al., 2003).

Thus, previous results show the pitfalls of positioning a product on process characteristics, which have little or unclear effects on those quality dimensions of the product which are accessible to consumer experience. Process characteristics may affect the formation of quality expectations more as a general quality indicator than as a single attribute.

On the other hand, reduced growth rates in organic pig production can be a good starting point for high sensorial quality of pork due to antagonistic relationships between traits related to performance and those related to sensorial quality. However, sensorial quality of meat does not occur automatically when extensifying the production process but needs special management skills to balance the various relevant factors in a comprehensive approach. Therefore, organic farming can not per se claim to produce high sensorial quality products but has the potential to do so if appropriate management tools are put into place. Instead of serving images in the eyes of the beholder, organic pig production is challenged to produce and offer pork products with clear and defined qualitative traits, thereby making the difference between a cheap no name product and a premium product.

9 Conclusion

Quality is a multi-factorial concept including a large number of factors that have to be taken into account, which are heterogeneous in the outcome and also in the perception of the stakeholders and the consumers. The current situation is characterised by a huge inconsistency between expectations and reality in relation to the level of different pork quality traits, and the uniformity of products in different production systems.

Although it is often emphasized by the pig industry, the previous pig production can not claim to be consumer-driven. Independently of the production method, criteria currently important to the farmer selling slaughter animals are not the same as those determining the pork quality after slaughter. Although striving for a high lean meat carcass has clearly reduced the fat content, thereby pleasing a majority of consumers, this progress has become self-employed as simultaneously the production costs decrease and economical gains increase.

Thus, pig production is constrained by circumstances which can not easily be changed despite the fact that eating quality of pork has decreased considerably. While the difference between 1.0g and 2.5g fat in a 100g chop is of negligible importance for the daily calorie intake of consumers it is of high relevance for the eating quality and for the production costs.

Pig production today faces the difficult task of effectively meeting emerging consumer concerns while remaining competitive on major target markets. Providing a high sensorial quality of pork and meeting consumer concerns about product safety and animal welfare are identified as key attention

points for future livestock production. The relevance of these issues pertains to production efficiency and economic benefits and to re-establishing meat sector image and consumer trust.

In current practice, the evaluation of carcass according to the EUROP grading system is almost the one and only method used throughout Europe for quality forecasting, although it is a quantitative rather than a qualitative trait. The previous approach has been very successful to produce lean meat on a low cost base. It provides, however, the disadvantage that antagonistic relationships between quantitative and qualitative traits as well as the negative side effects of maximisation of meatiness on animal health have been easily neglected due to a lack of data and consequences. Moreover, focussing only on quantitative traits and more or less ignoring quality traits does not enable to diminish the huge variation between products in relation to quality traits. As a consequence, quality is decreasing and commute to a low level.

The huge variation in intrinsic and extrinsic quality traits of pork can not be covered by making a difference between conventional, low-input or organic pig production. There are various traits in product quality where the values overlap to a high degree, while the traits of process quality are more specific to one of the three production methods. However, differences in product and sensorial quality between production methods seem to be primarily due to the difference in the variation within the production method rather than related to characteristic traits. Standardizing of framework conditions of production (final crossbreeds, feeding regime, housing conditions etc.) are of high importance in relation to quantitative traits while their effect on qualitative traits is an open questions due to lack of information.

There is reason to assume that the variation in quality traits are primarily due to the interactions between single factors. Source of variation (availability of essential amino acids, feed intake, feed digestibility, protein accretion between genotypes, stress through crowding effects, lack of space allowance, deficits in air condition or challenges through pathogens etc.) varies to a high degree between farms. To reduce variation therefore requires the development of strategies that are more closely related to the farm specific situation.

The complexity of the quality issue provides difficulties for the perception of quality by stakeholders and consumers giving each person the possibility to highlight those aspects he or she is in favour with and neglect or even ignore aspects which are not yet or difficult to fulfil. Due to different view points, preferences and perceptions with regard to pork quality the current situation is confused and lack clarity. Each producer and also each consumer has generated an image about what a high quality of pork should encompass. This image is based on individual principles of interpretation and concept of meaning which are developing throughout life by tradition, learning, conscious thinking and reflection, social activities or by own sensorial experiences. People seldom reflect on their own concept of meaning in relation to quality but take their own concept as reference system to relate and integrate new information and new experiences. At least each person has his individual 'quality concept'.

Currently, consumers have considerable difficulties in evaluating pork quality, resulting in uncertainty and dissatisfaction. It is apparent that little progress will be made until a firm resolution is taken by all involved in the production chain. A first step out of the current confused situation is a direct measurement of quality traits and a feed back to the farmers, so that they can react to this information. Simultaneously, it is important to honour pork with quality above average by adequate premium prices. Nonetheless, it is important to inform the consumer about the distinguishing traits. As it is to expensive to measure all relevant quality traits, it would be a start to begin with the most relevant such as pH-value, conductivity and IMF as criteria with a high meaningfulness in relation

to eating quality, pathological findings relevant for the animal health and welfare status, nutrient balance sheets of producing pig farms for the assessment of environmental impacts. Only information that is directly related to intrinsic and extrinsic quality traits will enable the consumer to decide within the different offers what fits most to the specific preferences and perception. It can be expected that most of the consumers are able to deal with the relation of cost benefit if transparency is clearly improved. The ever-increasing customer demands become more and more complex and may turn to disappointment when quality production can not hold the ground towards the expectations. Thus, there is ample room for the development of differentiated products, both in terms of improved intrinsic and extrinsic traits providing a big challenge for the pig industry and the pork marketing.

Concurrent inclusion of multiple control trades must be general practice, if the pork producing units are to be successful in the future. Production concepts taking several quality characteristics into consideration are most obviously handled in quality assurance (QA) schemes, which can guarantee the customer of the products that the relevant characteristics are included in the concept. Only those production chains that will be able to create a high correspondence between the different interests of stakeholders, and consumers within the whole production chain, and provide consistent, and trustful strategies can expect to develop a sustainable production chain that can face the challenge of consumer expectations and is prepared for the upcoming subsidy-free global market and the competition with the growing export-oriented, low-cost pork producing regions outside of Europe.

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