POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2006, Vol. 15/56, No 3, pp. 249–256

CRITICAL POINTS IN THE DEVELOPMENT OF PORK QUALITY – A REVIEW*

Andrzej Pisula, Tomasz Florowski

Department of Food Technology, Warsaw Agricultural University, Warsaw

Key words: pork quality, critical points, genetic traits, environmental traits, culinary pork

Pork is the most common consumed meat both in Poland and in the world. Unfortunately, in the last few years, a deterioration in quality has been observed by the meat industry as well by the consumers. When there was insufficient volume of pork on the market, meat industry had to process any quality of available raw material, however nowadays the requirements of consumers and processors need to be priorities for animal producers. Shaping of meat quality is a very complicated problem. The quality of pig carcasses and pork is determined by several factors, both genetic and environmental. In the last few years very intensive research in genetics has been carried out. In the future results of these projects will permit modeling of different features of meat quality in order to satisfy requirements of consumers. A number of research projects in this field have focused on the influence of animal nutrition, especially addition of easily assimilated sugars, compounds modifying metabolism and composition of fatty acids in animal feed. Additionally, it has been shown in these projects, that all improvements in genetic potential and animal feeding can be wasted by improper handling of animals during transport to slaughterhouses and technological mistakes during slaughtering processes. It means that modeling of pork quality requires control over a number of various factors at all stages of technological processes of its production.

INTRODUCTION

The world pork production amounts to about 100 million tons annually and is dominated principally by China (about 30%) and Europe (about 21%). Within the latter, the countries of the European Union are the largest producers and to a considerable degree also the largest consumers. The production of pork in the EU amounts to 21 million tons annually and is almost totally for local consumption. The export of pork from Europe to Japan and processed meat to the USA constitutes only a small share of the total production. Over the last 10 years the production of pork in the EU has not changed much but the quality requirements have increased significantly. This tendency was reflected in the EU Sixth Framework Programme, which in the fourth research priority, entitled "Food quality and safety", has included (in point T5.4.1.1) the project "Improving the quality of pork and pork products for the consumer". It is also important to observe a significant change in the EU requirements as regards the quality of raw material for food production. Until recently, facing their deficit, food technologists had to process every available raw material and request its adequate quality. The saying "from farm to fork" reflected this situation. Currently, the EU promotes the saying "from fork to farm", which univocally emphasizes that the production of raw material must be subjected to the requirements of the food manufacturers and consumers. This new tendency must be implemented also in Poland.

In year 2004, the production of pork in Poland amounted to 2 million tons, obtained as a result of the slaughter of over 23 million pigs. Over the same period the consumption of meat in Poland reached 65 kg per head, of which 65% was pork.

Beside the Czech Republic and Germany, Poland counts among countries with the highest share of processed meat consumption (about 50%) and pork is the principal raw material for the production of processed meat. From the 16 primal cuts obtained from a pig carcass, ham and porkloin are the major cuts used as culinary meat. Simultaneously, both those primal cuts are a valuable material for the production of cured meats. Currently about 40% of hams and pork loins are designated for the production of processed meats.

In the opinion of consumers, especially of the older generation, who compare contemporary food to the traditional foodstuffs, the quality of processed meats has deteriorated considerably over the last dozen years. Nobody wants to accept that the contemporary processing plants receive an utterly different raw material from that produced in the past, and traditional products are available only to a narrow group of society, principally because of the high price. Moreover, the concept of quality cannot be limited to sensory impressions only. For the contemporary consumer other criteria of quality are important as well, namely: health safety, nutritive value and usability (ease of preparation, shelf life, unit size, *etc*.). According to the unanimous opinion of food and nutrition specialists one may observe a considerable progress in food

Author's address for correspondence: prof. Andrzej Pisula, Department of Food Technology, Warsaw Agricultural University, Nowoursynowska 159C, 02-787 Warsaw, Poland; tel.: (48 22) 593 75 30, fax: (48 22) 593 75 31; e-mail: andrzej_pisula@sggw.pl

safety in Poland over the last several years, including that of meat and processed meat. This is of considerable importance to the position of Polish producers on the international market. In order to meet the requirements of local and foreign consumers it is, however, necessary to fulfil the high quality requirements, both as regards culinary meat and the material for processing as well as of final products.

In the case of culinary meat the most important criterion taken into consideration at the moment of purchase is the result of a visual evaluation. The consumer observes the share of individual tissues (principally meat, bone and fat) as well as the colour of meat. The colour of pork should be light red and any divergences are, not always correctly, treated as an indication that the meat is no longer fresh. An excessive natural drip is also undesirable. In turn, during consumption the greatest attention is paid to the taste, tenderness, juiciness and nutritive value [Wood *et al*., 1994].

Meat used for the production of cured meats, sausages and canned food must show a specific tissue composition and be characterised by a good processing quality, indicated by a high water holding capacity, good emulsifying capacity, high gel formation capacity, small cooking loss as well as adequate tenderness, juiciness and taste [Wood *et al*., 1994; Żak, 2000]. Considerable attention is also paid to the oxidative stability of meat as this has a direct effect on the shelf life of meat products. Moreover, both culinary and processing meat should be characterised by a low level of microbiological contamination and absence of any pharmaceutical compound traces [Wood *et al*., 1994; Fischer, 2001].

The modern meat processing industry, due to the possibility of using various functional additives and new technological solutions, is able to process raw meat of any, even low, quality. However, this leads to inevitable measurable economic losses, linked with changes in technology, the cost of functional additives and the necessity to perform a precise quality classification of meat prior to processing, which allows the selection of the most appropriate technology.

For many years the improvement of the percentage of lean meat in the carcass (leanness) of porkers constituted the principal goal of pig breeding in Poland. Unfortunately, with the increased leanness of carcass one may also observe a higher frequency of defective meat. The quality problem refers principally to an excessive drip loss, low water binding capacity and poor meat palatability after thermal processing. Beside meat with PSE, ASE and DFD defects one may observe an increased frequency of other quality defects, such as RSE (reddish-pink, soft, exudative), PFN (pale, firm, normal), the roots of which are not yet fully known. The only effective method of stimulating the production of porkers characterised by the production of high quality meat, is linking the evaluation of leanness with indicators of culinary and processing quality and introducing both those criteria into financial settlements with producers [Borzuta, 1998b].

A model porker should be characterised by a pre-slaughter live body weight of 90–110 kg, carcass leanness class E, fat thickness at point C_7 below 12 mm, loin eye area exceeding 40 cm^2 and meat without symptoms of quality defects [Borzuta, 1998a].

According to a number of authors [Meller, 1973; Meisinger, 2002; Rosenvold & Andersen, 2003], pork quality traits depend on genetic and environmental factors and on the interactions between them. Among the genetic factors are the animal's utility type and breed, sex as well as genetic susceptibility to stress. Among the non-genetic factors are the animal's age and physiological state as well as the external environmental conditions. The latter, depending on the place of occurrence, are divided into those effective during the rearing of porkers, during the preslaughter management of animals, in the slaughter houses and processing plants, during the commercial management of meat and its products and also during various culinary processes [Łyczyński & Pospiech, 2003; Nienartowicz-Zdrojewska, 2004]. It is accepted that genetic factors determine the quality of pork in about 20–30%, whereas the other 70–80% depend on the environmental factors [Koćwin-Podsiadła, 2002]. One must remember, however, that both those factors are of importance in pig breeding. Poor environmental conditions in the rearing of pigs with a high genetic potential will render impossible a full manifestation of the favourable traits of the porker, similarly as excellent rearing conditions will not produce good effects if the porkers are of a low genetic potential.

THE CHOICE OF BREED OR LINE

It is nothing new for the meat industry to pay attention to genetic factors when producing processed meats of high culinary and technological quality. In some regions of the world traditional cured meats are produced for generations and use is only made of meat from specific pig breeds, *e.g.* the Hungarian speciality known as the paprika sausage is produced from the meat of a local pig breed – Mangalica [Incze, 2003] or the production of traditional Spanish "Iberico" hams, produced from the meat of Iberian pigs or pigs of a local black breed [Jankiewicz & Słowiński, 2000]. In Polish conditions improving the quality of pork through the selection of breeds may also involve the use of local breeds. A study by Buczyński *et al*. [2003] has indicated that the meat of pigs of local breeds Złotnicka White and Spotted scored a much higher culinary quality than that of pigs from mass production. Such meat, due to a high intramuscular fat content, desirable colour and consistency, as well as exceptional taste, may in future become a material desired and competitive both on the Polish and the European market.

The desired properties (marbling) of the meat of the Puławska pig are also emphasised. Currently, attempts are being made at intensifying the reproduction of purebred Puławy pigs in order to obtain raw material for the production of high quality dried products, such as the "Lublin" pork loin, of specific taste characteristics [Kasprzyk & Walkiewicz, 2004]. However, the use of local breeds for the production of high quality pork is currently conducted on a small, experimental scale.

HALOTHANE AND NAPOLE GENES

Another factor which must be analysed when considering the quality of pork produced is the genetic predisposition to produce defective meat. According to the current knowledge two meat defects: PSE and ASE, are conditioned genetically. The occurrence of PSE meat is determined by a recessive gene Hal^n (halothane) while the presence of acid meat by a dominant gene RN^- (Napole). The halothane gene is considered to be the major gene for meat leanness. The selection of pigs for high muscle leanness is often accompanied

by an increased susceptibility of animals to stress factors. Pigs responding to those factors by a development of symptoms, including *e.g.* muscle shivering, difficult breathing, cyanosis and an increased body temperature which may change into malignant hyperthermia, demonstrate an increased mortality and tendency to produce PSE meat [Janik & Barowicz, 1998; Hinc & Wróblewski, 1999]. The increased susceptibility to stress is caused by an error in the ryanodine receptor gene of the sarcoplasma reticulum calcium channel, resulting in disturbances in the release and binding of calcium ions in the space surrounding myofibrils and thus in the dynamics of muscle contraction [Pospiech & Borys, 2004].

The PSE meat is characterised by a low pH, light colour and considerable drip loss. From the point of view of technology, the PSE meat, beside a lowered technological yield, poses additional problems related to the colour intensity of cured meat, which in the production of traditional hams may lead to a patchy-looking cross-section. Moreover, such meat binds more salt, which may result in over salty cured meats. In extreme conditions, the consistency of products made of PSE meat is very soft [Jankiewicz & Słowiński, 1999]. For this reason PSE meat should be eliminated from the production of cured meats, and the meat industry is interested in its reduced occurrence.

About 75–100% of porkers with Hal^nHal^n genotype (susceptible to stress), 23–28% of Hal^NHal^n heterozygotes and 0-17% of homozygotes resistant to stress are burdened with the PSE defect [Koćwin-Podsiadła, 1997; Janik & Barowicz, 2001; Kortz *et al*., 2004]. This defect rarely covers the whole muscle composition of a carcass and usually develops in the most valuable cuts [Strzelecki & Borzuta, 2002]. The occurrence of PSE meat in animals without the stress susceptibility gene requires further studies, as this indicates the presence of other genetic and environmental factors, responsible for its appearance [Janik & Barowicz, 2001].

The frequency of occurrence of stress susceptible pigs varies depending on the animal's breed, and even line. The stress susceptibility gene appears most often in the Pietrain breed, known for its high muscle leanness (91–98%). The use of boars of this breed, as well as crosses with Pietrain breed, clearly increases the frequency of the PSE meat in the porkers [Eckert & Żak, 1999]. Borzuta *et al*. [2003] demonstrated that in Polish conditions it is possible to breed porkers with a high muscle leanness, producing good quality meat, without crossing with the Pietrain breed. One must, however, emphasise that obtaining good quality meat from pigs with a high muscle leanness means undertaking necessary tasks beginning with breeding work, the production of porkers, slaughter and ending with meat processing. Of special importance here are pre-slaughter factors [Pospiech *et al*., 1998; Grześkowiak *et al*., 2001]. However, according to a number of authors, it is advisable to limit the meat muscle pork carcass leanness to a level of 56% [Gajewczyk, 2000].

Contrary to the halothane gene, the Napole gene has no significant positive effect on muscle development in the carcasses. The meat of porkers, carriers of allele RN^- (mostly of the Hampshire breed and crosses with this breed) is characterised by a low ultimate pH, high losses during thermal processing, high water and low protein content. The acid meat defect is linked with a high glycolytic potential of the muscles and prolonged process of meat acidification after slaughter [Monin & Sellier,1985; Koćwin-Podsiadła *et al*., 1996; Koćwin-Podsiadła, 1998ab].

In some cases, however, the presence of the Napole gene may be considered a favourable trait in the pigs bred. This depends on the possibility of processing acid meat in the given country. Meat obtained from pigs burdened with the RN^- gene may be used for the production of raw fermented hams, known for their specific taste and aroma [Lundström *et al*., 1996; Koćwin-Podsiadła, 1998ab]. Moreover, Borzuta *et al*. [2002] suggest that acid meat (ASE) may be used for the production of dried and semi-dried sausages. For the producer of this type of products contracting Hampshire pigs may be advisable as a method of improving efficiency and quality of the product.

INTRAMUSCULAR FAT

The quality of pork is also increasingly connected with the content of intramuscular fat. Thin fat fibres should be delicately and evenly distributed throughout pork meat, as after cooking this guarantees a desirable taste, tenderness and juiciness. It is accepted that for an optimum taste the intramuscular fat content of meat should amount to 2.5–3%. If the fat content exceeds 3.5% it may lead to a lowered consumer desirability [Wood *et al*., 1994; Fernandez *et al*., 1999; Meisinger, 2002].

Intensive breeding work aimed at the improvement of the carcass leanness in the mass pig population, conducted over many years, has led to a reduction in the content of intramuscular fat. With the increasing share of meat in the carcass one can observe a decrease in the deposition of fat, both subcutaneous and intramuscular. The positive effect of this tendency is obtaining "dietetic" meat which is valued by some consumers, but the decrease in intramuscular fat has an unfavourable effect on the taste of pork. Thus it would be advisable to include the content of intramuscular fat in the selection index for pigs [Daszkiewicz *et al*., 2003].

MUSCLE FIBRE TYPES

The currently used selection methods prefer breeds and lines demonstrating muscle hypertrophy, especially in the ham and shoulder. A considerable increase in the volume of individual muscles has been observed to result from an increased diameter of muscle fibres and not from an increase in their numbers. Together with the increase in diameter in a considerable part of the fibres the metabolism changes from predominantly aerobic (in normal fibres) to anaerobic, dominating in "gigantic" fibres. This phenomenon, beside an unfavourable effect on the consistency of culinary meat, is of a considerable importance for the post-slaughter changes in acidity and meat quality indicators connected with this process (principally water holding capacity). It would be advisable to direct further genetic studies towards identifying those breeds and lines in which the increase in muscle weight is caused by an increase in the number of fibres and not in their diameter.

FEEDING – CONTROLLING THE *IN VIVO* LEVEL OF GLYCOGEN

It is generally known that the quality of pork may be influenced by the feeding of pigs. The greatest attention is current-

ly given to the content of easily assimilable carbohydrates in feeds, the composition of fatty acids in the feed and the addition of components modifying the metabolism.

The addition of easily assimilable carbohydrates to the feed of animals is supposed to ensure a correct level of glycogen in the muscles, as this is a prerequisite for the correct progress of *post-mortem* aging of meat and protects meat against the occurrence of a series of technological defects, principally DFD. Feeding pigs on feeds supplemented with saccharose and other easily assimilated carbohydrates for several days prior to slaughter substantially increases the level of glycogen and thus ensures a correct pH in mature meat. However, this is a short-term effect and may be totally destroyed by a long-lasting (*i.e*. one night) fast or stress caused by the fighting between groups of animals mixed together in pre-slaughter lairage.

Decreasing the level of glycogen by feeding pigs over a period of three weeks on feeds with high levels of fat and protein and a comparatively low content of easily assimilated carbohydrates may, however, result in a lowered level of glycogen in the meat, without causing significant changes in the physicochemical properties. Lauridsen *et al*. [1999] demonstrated that the meat of pigs fed a standard feed with an increased fat content had a lower level of glycogen before slaughter, which led to an increased water holding capacity. According to the authors, this situation was not due to a lower level of pH in mature meat (compared to meat of control animals) but rather to a slower post-slaughter acidification.

FEEDING – COMPOUNDS MODIFYING THE METABOLISM

Metabolism-modifying compounds are still considered controversial and their use is forbidden in many countries. Their application is aimed at improving the fattening and slaughter traits of animals or the quality of meat. Among the metabolism-modifying compounds one may distinguish antibiotics, ionophores, anabolic steroids, somatotropin, compounds of the fenyloethanoloamine type and vitamins, offered in quantities exceeding the requirements of the organism [Pospiech & Borys, 2004].

Supplementing the pig feed with antibiotics (treated as growth stimulants) is aimed at limiting the bacterial flora, increasing growth rate and improving feed conversion. Concentrates for piglets are supplemented principally with avilamycin and flavomycin. However, one may observe a tendency for withdrawal of antibiotics from animal feeding, as in feeds they are considered to be the cause of a distinct increase in the counts of pathogenic microorganisms resistant to the antibiotics used in treating human and animal diseases [Kamyczek, 2004].

Anabolic steroids are also among the important metabolismmodifying compounds. Their use enables increasing weight gains and improving feed conversion, but simultaneously may result in an increased susceptibility of animals to stress and thus have a negative effect on meat quality. Those compounds are not allowed in pig feeding [Pospiech & Borys, 2004].

The widely advertised somatotropin, belonging to steroid-like compounds, also has a positive effect on fattening and slaughter traits and particularly on feed conversion and carcass leanness. However, an addition of somatotropin may result in deterioration of meat quality, and particularly poorer tenderness, colour and tissue binding [Pospiech & Borys, 2004].

Among vitamins, special attention should be paid to vitamin E. Its accumulation in the muscle tissue and antioxidative activity leads to a decrease in lipid and myoglobin oxidation in the meat and thus to an improvement of its technological and storage properties. An addition of vitamin E affects the oxidation stability of triglycerides and decreases the oxidation of phospholipids, which results in less aroma defects in raw and processed meat [Fischer, 2001]. Some authors emphasise also the positive effect of the addition of vitamin E to the feed on the stability of meat colour and decreased natural drip [Monahan *et al*., 1992; Meisinger, 2002; Rosenvold & Andersen, 2003; Pospiech & Borys, 2004]. More controversial is feed supplementation with high doses of vitamin D_3. Main reservations relate to the potential toxicity of high deposits of vitamin D_3 in the meat and liver to consumers. The addition of vitamin D_3 to feed results in improved meat tenderness in the first period *post-mortem*, as the increased level of calcium in blood and muscle increases the activity of calpain and decreases drip loss.

The processing properties of meat may also be affected by enriching the diet with magnesium and tryptophane. Their addition to the feed several days before the planned slaughter may have a positive effect on the quality of meat, because they limit the frequency of occurrence of the PSE defect (decreased drip loss, improvement of colour and increased meat acidity) [Otten *et al*., 1992; D'Souza *et al.,* 1999].

FEEDING – FATTY ACID COMPOSITION

As the quality of meat is increasingly linked with its safety, the interest in feed supplements which may affect fatty acid composition is also observed to increase. Pork, commonly considered as high in fat content, is not accepted by those consumers who treat seriously the health-promoting properties of food. As this group of consumers is increasing, attempts are being made by producers to modify the composition of fatty acids in the pork fat to make it more healthy. The principal goal is to increase the level of polyunsaturated fatty acids from the omega 3 family (*e.g.* linolenic acid, eicosapentaenoic acid, docosahexaenoic acid) which are significant factors in the protection against sclerosis and an important component of the nervous tissue. Pork meat is characterised by an unfavourable ratio between the polyunsaturated acids of the omega family 6 (*e.g.* linoleic acid) and those of the omega 3 family. The desirable ratio ranges from 1 to 3, whereas in lean pork it amounts to 7–8 [Kulisiewicz & Więcek, 2000]. Polyenic, polyunsaturated fatty acids cannot be synthesized during metabolic processes in pigs and must be consumed with the feed. Fischer [2001] reports that with a supplement of 2.5% of linseed oil one may increase the content of linolenic acid in the back fat from 1–2% to over 9%. Recently, a considerable interest has focused on the addition of conjugated linoleic acid (CLA) to the feed for pigs. This compound shows an anticarcinogenic activity and limits the incidence of atherosclerosis. In pigs receiving feed with an addition of CLA one may observe a decrease of back-fat

thickness and increased carcass leanness, without changes in meat quality [Pospiech & Borys, 2004].

However, enriching pork fat with polyunsaturated fatty acids may pose a problem as regards the technological and shelf life of meat. A high level of polyenic acids leads to a poorer consistency of the fat tissue and increases its susceptibility to oxygenation. The oxygenation of fat is one of the principal factors lowering the quality and shelf life of raw and processed meat. As a result of oxidation, aroma is subject to changes, among others a rancid aroma appears, especially after heating the product [Gray *et al*., 1996]. Low oxidation stability poses a special problem for the production of dried products, among others fermented raw sausages. Back fat for the production of such products should be hard and have a low susceptibility to oxidation. The raw material for the production of such products should be characterised by low levels of polyunsaturated fatty acids.

FATTENING SYSTEM, *AD LIBITUM* FEEDING

The technological, sensory and nutritional quality of meat may also be modified by changing the conditions of fattening. Irrespectively of the fattening and slaughter properties of pigs, regulating the quantities of feed offered makes it possible to change the content of intramuscular fat and thus the sensory quality of the pork produced. This is of considerable importance both for the production of culinary pork and the raw meat for processing. Numerous authors indicate that feeding pigs *ad libitum* significantly increases the marbling of meat [Wood *et al*., 1994; Meisinger, 2002]. Recently, a combined system of fattening pigs is gaining popularity. In this system the daily diet is limited after the pigs reach 70 kg of live body weight and two weeks before slaughter the *ad libitum* system is restored in order to increase the content of intramuscular fat [Łyczyński, 2002; Łyczyński & Pospiech, 2003].

PRE-SLAUGHTER FASTING

The principal aim of pre-slaughter fasting is to facilitate evisceration and to improve the hygiene conditions of slaughter by limiting the possibilities of cross infection. If fasting takes place on a farm another important element is the emptying of the digestive tract before transporting the animals to a slaughter house.

Prolonging the pre-slaughter fasting over 24 hours has a positive effect on the increase in the pH of mature meat, water holding capacity and meat colour, but due to the necessity of meeting the animal welfare requirements and loss of body weight it is not used in practice.

TREATMENT OF ANIMALS ON A PRODUCER'S FARM AND DURING TRANSPORT – LIMITING STRESS

An incorrect treatment of animals on a farm, during transport and directly before slaughter causes stress, which may have a considerable negative effect on meat quality. Stress induced by wrong conditions during growth and fattening, mixing strange groups of animals, loading and transport is comparatively long lasting and has a significant effect on the appearance of DFD meat. In turn, stress caused by the improper treatment of animals directly before slaughter is of short duration and favours the appearance of the PSE meat defect.

During growth and fattening the conditions in which animals are maintained (size of boxes, possibility of movement, light, contact with people, the use of electric drivers) are among the most stress-bearing factors. It is recommended, though in practice difficult to introduce, to drive animals during the fattening period so as to get them used to conditions directly before loading.

The mixing of animal groups, which leads to fights between the leaders wanting to determine the "pecking order" in the newly created flock, is undoubtedly the most stress-bearing factor. Such fights result not only in wounds but also in an exhaustion of the supply of glycogen, which in turn leads to the DFD meat defect.

Thus all manipulations connected with the movement and transport of animals must be performed with care and taking into consideration the animals' welfare, *i.e*. ensuring such conditions in which the environmental stimuli affecting the nervous system will remain within a range possible to accept by the organism of the animal [Walczak, 2003]. Of course, the most susceptible to stress-bearing factors are animals burdened with the halothane gene, but all manipulation should be performed with consideration for the animals' welfare, irrespective of their breed and including those "resistant" to stress.

ANIMAL TRANSPORT

Animals should be moved exclusively in suitable adapted means of transport, rendering it possible for the animals to retain their balance and protecting them against unfavourable environmental factors. Animals should be transported in groups in which they were reared. If the transport lasts over 12 hours, the animals must be watered and fed. It is recommended that the drivers are specially trained as regards conditions of animals transport.

In lairage before slaughter the animals must have continuous access to water and, if they are kept there over 12 hours, also access to feed. Simultaneously, it is recommended that animals transported over short distances are slaughtered directly after arriving at the slaughter house [Pospiech *et al*., 1998; Nienartowicz-Zdrojewskia, 2004].

Rest before slaughter limits the stress of animals caused by transport. After about 2 hours in the pre-slaughter lairage the animals stop fighting and calm down. A pre-slaughter rest of 2–4 hours is considered optimal. Prolonging the time spent by animals in the pre-slaughter lairage increases the amount of skin damage and creates conditions for the appearance of the DFD defect. The slaughter of animals directly after they arrive at the slaughter house, or after a shorter rest period, increases the frequency of the occurrence of PSE meat to a considerable extent.

THE EFFECT OF SLAUGHTER PROCESSES – SLAUGHTER AND POST- SLAUGHTER TREATMENT

Among the slaughter factors affecting the quality of the meat produced, special attention should be paid to the technique of animal stunning. Recommended is electric stunning (over 300 V) and pharmacological stunning (CO_2). Both

those methods enable a humanitarian slaughter, though the use of the pharmacological method results in a better quality meat than the electric stunning – the number of bruises is smaller and the PSE defect occurs less frequently [Barton-Gade *et al*., 1992; Channon *et al*., 2002; Meisinger, 2002; Rosenvold & Andersen, 2003].

The time span from the moment of stunning to the beginning of bleeding also plays an important role in limiting the frequency of meat quality defects. When using the electric stunning method this time should be limited to a maximum of 20 seconds. This prevents the appearance of bruises and blood splashes and also inhibits the stress hormone from spreading over the entire animal body and stimulating the glycolysis processes [Pospiech *et al.,* 1998; Łyczyński & Pospiech, 2003].

In several American slaughter houses animals are bled in a horizontal position, as this shortens the time from stunning to bleeding and because animals that are not hanged by one leg show less bruises. Five minutes is considered the maximum acceptable time for bleeding. Prolonging this period may have a negative effect on the tenderness of meat.

Subsequent post-slaughter operations, such as scalding, evisceration, halving, veterinary examination, evaluation of carcass leanness *etc*., have no significant effect on the quality of pork, as long as they are performed in accordance with good production practice. It is important to limit the time in which those operations are completed so as to start the post-slaughter chilling as soon as possible (in total the time from stunning to the beginning of chilling should not exceed 30 minutes).

POST-SLAUGHTER CARCASS CHILLING

The post-slaughter quality of pork is significantly affected by the correct carcass chilling. A quick chilling is favourable both for microbiological and technological reasons. It decreases the rate of post-slaughter glycolysis and limits the occurrence of meat with low water holding capacity. However, the effect of chilling on the occurrence of the PSE meat defect depends on the rate at which the pH value decreases [Offer, 1991]. Excessive chilling of carcasses may result in a cold shortening, which has a negative impact on meat tenderness.

Improvement of meat quality (tenderness) may be obtained by hanging the carcass by the aitchbone on completion of the slaughter operations. This leads to the stretching of the muscles and thus the sarcomeres, which improves the tenderness and water holding capacity of meat.

THE EFFECT OF POST-SLAUGHTER PROCESSES ON PORK QUALITY

The correct cutting of the carcass into primal cuts and next into culinary and processing meat determines, to a considerable degree, the economic efficiency of a plant.

Lately the fact that culinary pork must age before it reaches the desired sensory quality (principally tenderness) is emphasized. In a cooler this process may last up to 10 days after slaughter.

In the processing of pork it is of considerable importance to select the correct functional additives, which will improve the palatability properties of the product and simultaneously positively affect the economic efficiency.

In the case of freezing meat, the rate of the process, measured by the length of time needed to lower the temperature from 5°C to -12°C, considerably affects the quality of meat, and principally the volume of drip loss after defreezing.

The packing systems, *e.g.* vacuum packing and packing under modified atmosphere, may significantly prolong the shelf life both of culinary and processed meat.

The technique and parameters of the thermal processing of pork are significant for emphasizing the desired sensory profile. In order to obtain an optimal aroma frying is recommended, whereas optimal texture parameters are obtained through roasting. Such properties as thermal drip and juiciness are also very important parameters of pork quality.

SUMMARY

The quality of pork is dependant on a series of pre- and post slaughter factors. For this reason pork quality may be modified depending on the required culinary or processing parameters. Most of the studies conducted so far concentrated on determining the effect of individual factors on the major meat parameters. As the genetic, breeding and nutritional possibilities in animal breeding together with slaughter and processing techniques are changing continuously it is necessary to use the knowledge gathered in an optimal manner so as to be able to control the quality of meat depending on the proposed mode of utilisation while simultaneously retaining an economic efficiency.

*The paper has been presented at the international conference "Quality of Meat and Meat By-Products. Present Situation and Perspectives in Its Improvement", held on the 14–15 September 2005 in Baranowo, Poland.

REFERENCES

1. Barton-Gade P.A., Blaabierg L., Christensen L., New lairage system for slaughter pigs – effect on behavior and quality characteristics. Proc. 38 ICoMST, Clermont--Ferrand, France, 1992, 161–164.
2. Borzuta K., Grześkowiak E., Strzelecki J., Tratwal Z., Is there a chance in Polish conditions to get high percentage of lean meat in four breed crosses without using Pietrain breed? Trzoda Chlewna, 2003, 4, 28–30 (in Polish).
3. Borzuta K., Strzelecki J., Grześkowiak E., Fast industrial methods of selection of pig's carcasses. Gosp. Mięsna, 2002, 1, 16 (in Polish).
4. Borzuta K., Classification of pig carcasses in Poland. 1998a, IPMiT, Poznań, 1–7 (in Polish).
5. Borzuta K., Advantages and disadvantages of pork obtained from pig carcasses with high percentage of lean meat. Trzoda Chlewna, 1998b, 11, 81 (in Polish).
6. Buczyński J., Swulińska-Katulska A., Chojnacka A., Estimation of culinary quality of pork from pigs Zlotnicka White and Zlotnicka Spotted breeds. 2003, *in*: Proceedings Intern. Conf. Genetic and breeding studies on Polish native pigs' breed. 18–19 November 2003, August Cieszkowski Agricultural University of Poznań, Department of Pig Breeding and Production. (in Polish).
7. Channon H.A., Payne A.M., Warner R.D., Comparison

of CO_2 stunning with manual electrical stunning (50 Hz) of pigs on carcass and meat quality. Meat Sci., 2002, 60, 63–68.
8. Daszkiewicz T., Wajda S., Bąk T., Intermuscular fat and eating quality of meat. Gosp. Mięsna, 2003, 2, 26–29 (in Polish).
9. D'Souza D.N., Warner R.D., Dunshea F.R., Leury B.J., Comparison of different dietary magnesium supplements on pork quality. Meat Sci., 1999, 1, 221–225.
10. Eckert R., Żak G., Encumbrance by PSE and DFD defects of meat from pigs crosses with different participation of Pietrain breed. Trzoda Chlewna, 1999, 4, 18 (in Polish).
11. Fernandez X., Monin G., Talmant A., Mourot J., Lebret B., Influence of intramuscular fat content on the quality of pig meat – 1. Composition of the lipid fraction and sensory characteristics of *m. longissimus lumborum*; 2. Consumer acceptability of *m. longissimus lumborum*. Meat Sci., 1999, 53, 59–65, 67–72.
12. Fischer K., Fleischfeler műssen nicht sein. Fleischwirtschaft, 2001, 10, 21.
13. Gajewczyk P., The trend to reach high percentage of lean meat in pork carcasses is slowly going down. Trzoda Chlewna, 2000, 4, 39 (in Polish).
14. Gray G.I., Gomaa E.A., Buckley D.J., Oxidative quality and shelf life of meats. Meat Sci., 1996, 43, 111–123.
15. Grześkowiak E., Borzuta K., Strzelecki J., Lisiak D., Changes in the quality of pork in Poland in comparison to meat in the European Union. Trzoda Chlewna, 2001, 4, 41–44 (in Polish).
16. Hinc S., Wróblewski A., Identification of genotypes of breeding boars used in the Breeding Station in Olecko. Trzoda Chlewna 1999, 2, 29 (in Polish).
17. Incze K., Ungarische Roh – und Dauerwürste. Fleischwirtschaft, 2003, 11, 30–34.
18. Janik A., Barowicz T., Quality of pork – influence of stress caused by pre – and slaughter processes. Trzoda Chlewna, 2001, 11, 72 (in Polish).
19. Janik A., Barowicz T., Development of methods for identification of stress in pigs. Trzoda Chlewna, 1998, 4, 17 (in Polish).
20. Jankiewicz L., Słowiński M., Technology of processed meats. Uncooked processed meats. Mięso i Wędliny, 2000, PWF, 5–16 (in Polish).
21. Jankiewicz L., Słowiński M., Technology of processed meats. Smoked cooked meats. Mięso i Wędliny, 1999, PWF, 7–18 (in Polish).
22. .Kamyczek M., Effectiveness of FOTMI preparate in piglets feeding. Trzoda Chlewna, 2004, 4, 49–51 (in Polish).
23. Kasprzyk A., Walkiewicz A., Genetic reserve in population of Pulawska breed. Trzoda Chlewna, 2004, 3, 22–27 (in Polish).
24. Koćwin-Podsiadła M., Methods for improvements of pork quality. 2002, *in*: Proceedings V Intern. Tradeshows. Pork and Poultry Farm. 17–19 May, Poznań, Poland, pp. 93–95 (in Polish).
25. Koćwin-Podsiadła M., Genetic factors modifying pork quality. Trzoda Chlewna, 1998a, 10, 79–86 (in Polish).
26. Koćwin-Podsiadła M., Defects of pork and their background. Trzoda Chlewna, 1998b, 1, 53–55 (in Polish).
27. Koćwin-Podsiadła M., Genes influencing quality of pork. Gosp. Mięsna, 1997, 10, 36–37 (in Polish).
28. Koćwin–Podsiadła M., Przybylski W., Kaczorek S., Krzęcio E., Quality characteristics and final yield from normal, PSE and "acid" pork. 1996, *in*: Proceedings XXVII Sci. Conference. The Development in Technology, Storage and Quality Control of Food. Department of Food and Chemistry Technology Polish Academy of Sciences, 27–28 June 1996, Szczecin, Poland, pp. 53–56 (in Polish).
29. Kortz J., Rybarczyk A., Pietruszka A., Czarnecki R., Jakubowska M., Kałmucki T., Effect of Hal genotype on normal and faulty meat frequency in hybrid fatteners. Pol. J. Food Nutr. Sci., 2004, 13/54, 4, 387–389.
30. Kulisiewicz J., Więcek J., Program for production of high quality pork. Wieś Jutra, 2000, 8, 9–11 (in Polish).
31. Lauridsen C., Nielsen J.H., Henkel P., Sorensen M.T., Antioxidative and oxidative status in muscles of pigs fed rapeseed oil, vitamin E, and copper. J. Anim. Sci., 1999, 77, 105–115.
32. Lundström K., Andersson A., Hansson I., Effect of RN gene on technological and sensory meat quality in crossbred pigs with Hampshire as ternimal sire. Meat Sci., 1996, 42, 145–153.
33. Łyczyński A., Pospiech E., Influence of environmental factors appearing in different stages of production on quality of pork.. Trzoda Chlewna, 2003, 3, 38–48 (in Polish).
34. Łyczyński A., Influence of genetic and environmental factors on quality of pork. 2002, *in*: Proceedings V Intern. Tradeshows. Pork and poultry farm. 17–19 May 2002, Poznań, Poland, pp. 88–89 (in Polish).
35. Meisinger D., A system for assuring pork quality. National Pork Board, 2002, USA.
36. Meller Z., Processing quality of pork from pig breeds Pietrain, Zlotnickiej and their crosses. Zesz. Ak. Rol.–Tech. w Olsztynie, 1973, 35, 79–89 (in Polish).
37. Monahan F.J., Asghar A., Gray J.I., Buckley D.J., Morrissey P.A., Influence of dietary vitamin E (α-tocopherol) on the colour stability of pork chops. 1992, *in*: Proc. 38 ICoMST, Clermont-Ferrand, France, pp. 543–546.
38. Monin G., Sellier P., Pork of low technological quality with a normal rate of muscle pH fall in the immediate *post-mortem* period: The case of the hampshire breed. Meat Sci., 1985, 13, 49–63.
39. Nienartowicz-Zdrojewska A., Environmental factors, holding and turnover of animals and their influence on pig carcasses and pork quality. Trzoda Chlewna, 2004, 2, 43–45 (in Polish).
40. Offer G., Modelling of the formation of pale, soft and exudative meat: Effects of chilling regime and rate and extent of glycolysis. Meat Sci., 1991, 30, 157–184.
41. Otten W., Berrer A., Hartmann S., Bergerhoff T., Eichinger H.M., Effects a magnesium fumarate supplementation on meat quality in pigs. 1992, *in*: Proc. 38 ICoMST, Clermont–Ferrand, France, pp. 117–120.
42. Pospiech E., Borys A., International Congress of Meat Science and Technology. Gosp. Mięsna, 2004, 7, 20–25 (in Polish).
43. Pospiech E., Borzuta K., Grześkowiak E.,The possibility of ante-mortem modeling of pig carcasses and pork quality. Gosp. Mięsna, 1998, 5, 28 (in Polish).
44. Rosenvold K., Andersen H.J., Factors of significance for pork quality – a review. Meat Sci., 2003, 64, 219–237.

45. Strzelecki J., Borzuta K., Symptoms of PSE in pig carcasses and industrial methods of pork selection. Gosp. Mięsna, 2002, 12, 26–28 (in Polish).
46. Walczak J., Animal welfare – what it is and haw it is possible to measure it? Trzoda Chlewna, 2003, 1, 93–99 (in Polish).
47. Wood J.D., Wiseman J., Cole D.J.A., Control and manipulation of meat quality. 1994, *in*: Principles of Pig Science (eds. D.J.A. Cole, J. Wiseman, M.A. Varley). Nottingham University Press, UK, pp. 433–456.
48. Żak G., High quality – trump in production of pork. Trzoda Chlewna, 2000, 47, 10 (in Polish).

Received August 2005. Revision received February and accepted March 2006.

PUNKTY KRYTYCZNE W KSZTAŁTOWANIU JAKOŚCI MIĘSA WIEPRZOWEGO – ARTYKUŁ PRZEGLĄDOWY

Andrzej Pisula, Tomasz Florowski

Katedra Technologii Żywności, Szkoła Główna Gospodarstwa Wiejskiego, Warszawa

Mięso wieprzowe jest najczęściej spożywanym mięsem zarówno w Polsce, jak i na świecie. Niestety, w ostatnich latach zarówno przemysł, jak i konsumenci wskazują na znaczne pogarszanie się jego jakości. Do niedawna w sytuacji niedoboru mięsa istniała konieczność przetwarzania każdego dostępnego surowca, jednak obecnie jednoznacznie wskazuje się, że priorytety obowiązujące w produkcji surowców muszą być podporządkowane wymaganiom przemysłu mięsnego i konsumentów. Problematyka kształtowania jakości mięsa stanowi niezwykle złożone zagadnienie. Jakość tusz i mięsa wieprzowego jest bowiem determinowana przez dużą pulę różnych czynników, zarówno genetycznych, jak i środowiskowych. W ostatnim okresie obserwuje się szczególne zintensyfikowanie prac nad genetycznym podłożem zróżnicowania jakości surowca wieprzowego. Ich wyniki mogą w przyszłości pozwolić na dokładniejsze modelowanie cech jakościowych mięsa, tak aby jak najlepiej odpowiadały one wymaganiom odbiorcy. Wiele prac badawczych prowadzonych jest również nad możliwością kształtowania jakości mięsa poprzez żywienie świń, szczególnie dodatku do paszy łatwo przyswajalnych cukrów, składników modyfikujących metabolizm oraz skład kwasów tłuszczowych. Dodatkowo, w programach poprawy jakości mięsa wieprzowego wskazuje się, iż wszystkie działania w aspekcie zapewnienia właściwego potencjału genetycznego świń i prawidłowego ich żywienia mogą być zniweczone przez niewłaściwe obchodzenie się z nimi w czasie transportu do zakładów ubojowych oraz błędy w ich uboju i obróbce poubojowej. Modelowanie jakości surowca wieprzowego wymaga zatem uwzględnienia wielu, zróżnicowanych czynników działających na każdym etapie jego produkcji.