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Nutrition and meat quality*

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S u m m a r y: There are numerous factors which influence the quality of pork meat (genetic basis, rearing conditions, pre-slaughter procedures, carcass treatment, cooling). It is understandable that nutrition is one of the major factors which influence the quantity and quality of meat. Main objective of proper nutrition is the best utilization of the genetic potential of pigs, and obtaining of meat which will satisfy the consumer or be used as raw material in manufacturing of meat products. Quality of pig meat is most often associated with pH value, colour succulence, tenderness, content of intramuscular fat (marbling), sustainability and, in general, acceptability by consumers. In this paper, the effect of certain modifications in pig nutrition on post mortal changes, selected technological properties of meat (pH value, water binding capacity, and colour), content of intramuscular fat, quality of fat and acceptability of meat is presented.

Key words: *pig meat, nutrition, quality.*

Introduction

Consumption of pig meat globally is constantly increasing and is superior to consumption of all other types of meat (beef, poultry). In nutrition of population in Serbia, consumption of pig meat is far greater than consumption of other meat types, so share of pork in total meat consumption is approx. 60%. Consumption of pig meat varies significantly in different regions of the World. It is known that certain religions do not allow use of pig meat in human nutrition. On the other hand, e.g. annual consumption of pork per capita in Denmark is over 60 kg (*Baltić et al.*, 2002; *Baltić et al.*, 2009).

Nutritive value of meat in human nutrition is well known, so the position that the meat constitutes the basis of human nutrition is understandable. In regard to pig meat, there are 14 key reasons why it is considered as nutritionally valuable. Namely, pig meat is exceptional source of proteins, vitamin B12, vitamin B6, thiamine, niacin, selenium, zinc and phosphorus. It is very good source of riboflavin and potassium, also of iron, magnesium and pantothenic acid. Meat is very good energy source, which mainly depends on content of fat in the meat. Pig meat can contain small amounts of sodium (55 mg/100g which is only 2% of daily requirement). This meat type doesn't contain, naturally, trans- or hydrogenized fats, which can be found in ruminants. Value of pig meat is also in the fact that it is used in production of various and highly valued meat products, some of them with very long tradition (*Baltić et al.,* 2010, *Jovanović et al*., 2009a).

Efforts are constantly made to produce more and more meat, including pork. This is achieved in different ways, primarily through genetic selection, nutrition, rearing conditions, etc. Efforts of meat producers, however, are not related only to increase of the production volume, but also are directed towards obtaining of meat of high quality, meat which will meet the requirements of more demanding consumers (*Baltić et al.,* 2010).

There are many factors which influence the quality of pig meat, starting with genetics associated

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factors, followed by nutrition, rearing conditions, handling of animals during loading into vehicles, transportation, depot, stunning, slaughtering and cooling of the carcass. Quality of pig meat is traditionally associated with pH value (45 minutes and 24 hours after slaughtering), colour of meat, texture, content of intramuscular fat, sustainability and acceptability for the consumer subsequent to heat treatment. The consumer, however, recently also in our country as well as in the World, is associating the quality of meat with rearing conditions (housing) for animals, their welfare and ethical issues. From the aspect of meat industry and their desire to satisfy the consumer, quality of meat is associated with safety, chemical composition, nutritional value and sensory properties of meat (*Jovanović et al.,* 2009b).

Nutrition of pigs is one of the major factors influencing the quality of meat. It has to be, first of all, balanced in such way to enable maximum use of the genetic potential of the animal during fattening. Nutrition of pigs and its impact on the quality of meat was always considered to be exceptionally significant. This influence relates to numerous meat quality parameters such as: meat safety (biological, chemical and physiological hazards); nutritional value of meat; post mortal changes in meat and its technological properties (pH, colour, water binding capacity); content of intramuscular fat; meat colour; fatty acid composition and stability of fat during cooling (freezing) and distribution; acceptability of meat to consumers subsequent to heat treatment (*Marković et al.,* 2010;).

Selection of feeds and their impact on meat odour and taste

One of the main tasks of animal nutrition is providing sufficient quantities of food for human population, food of exceptional value as excellent source of proteins, fats, vitamins and minerals which are necessary in human nutrition. Nutrition, among other things, is also way to influence the quality of meat, as well as sensory properties of meat which are of special importance to the consumer.

Reduced amount of energy in fattening mixtures for pigs does not affect the acceptability (taste) of pig meat. However, pork steaks obtained from pigs fed ad libitum had higher scores for tenderness and lower Warner Bratzler value of shear force (WBSF) compared to pigs fed 75% or 80% ad libitum, even though the content of total and soluble muscle collagen and myofibril fragmentation index (indicator of post mortal proteolysis) have not changed. In addition, numerous studies have shown that meat from pigs fed ad libitum, subsequent to sensory analysis, was given higher scores for odour and taste, succulence and general acceptability (*Daza et al.,* 2007).

Selection of cereal/grain, as a component in pig nutrition, can also have impact on acceptability of pork. Cooked pork steaks/cuts from pigs fed wheat had higher scores for taste compared to pork cuts from pigs fed sorghum, whereas pork steaks/cuts from pigs fed mixture of yellow and white corn in ratio 33%:67% or 67%:33% had higher scores for succulence and taste compared to pork steaks/cuts from pigs fed mixture of barley and yellow, or white corn. Also, it is known that meat from pigs fed wheat has lower WBSF value and higher scores for tenderness compared to pigs fed sorghum. It is also observed that pork steaks/cuts from pigs fed barley were scored in sensory analysis as more tender than pork steaks/cuts form pigs fed corn or mixture of barley and triticale. Contrary to this, WBSF value and score for acceptability of pig meat were similar in pigs fed yellow, white corn, wheat, sorghum or triticale (*Lampe et al.*, 2006; *Sullivan et al.*, 2007).

Value of shear force necessary for cutting of cooked pork steaks/cuts increases by almost 23% with the increase of crude protein content in the fattening mixture from 10 to 22%. Also, *Goodband et al.* (1993) established the linear increase of WBSF values in cooked pork steaks/cuts with the increase of content of lysine in food from 0,6 to 1,4%, whereas *Apple et al.* (2008) observed linear increase of WBSF values with the increase of lysine ratio to energy from 1,7 (0,56 to 0,59% of lysine) to 3,1 g/Mcal (1,02 to 1,08% of lysine) in mixtures for fattening. *Goodband et al.* (1993) also recorded decrease in sensory scoring of meat tenderness with the increase of lysine level in feeds. In general, increased level of lysine in pig nutrition has no impact on degree of succulence and taste of cooked pork.

Use of rape seed or/and fish oil influences incidence of unpleasant odour of roasted meat, and has impact on its general acceptability. Use of animal sources of fat has no considerable effect on fatty acid profile and sensory properties of meat, such as tenderness, succulence and intensity of odour and taste. Use of dried distillers grain (DDGS) in nutrition of pigs or addition of glycerol influences the decrease of WBSF values. It has not been proven that addition of conjugated linoleic acid (CLA) has effect on WBSF values or assessment of the acceptability of meat or fat/bacon (*Apple et al.,* 2008; *Engel et al.*, 2001).

It is known that there is a link between calcium content and meat tenderness. It is generally accepted that increase of calcium content leads to post mortal degradation of cytoskeleton due to the effect of calpain which contributes to meat tenderness. Vitamin D

is included in the intercellular mobilization of calcium and addition of considerable amounts of vitamin D in the nutrition for instance of cattle leads to the increase of its content in blood and meat, and most important, leads to enhancement of meat tenderness. Although the calcium concentration in plasma and muscles was increased by 125% in pigs fed finisher diet supplemented with vitamin D3, WBSF value, sensory evaluation of meat tenderness, as attributes which contribute to the acceptability of meat, were not changed. Interestingly, there are literature data presenting that adding of increased amounts of vitamin D3 in pig nutrition can have impact on meat freshness, including increased initial (45 minutes) and final pH value (24 hours), better subjective score of colour, as well as on „a" value of meat colour, reduction of „L" values of meat colour, and decrease of weight loss (*Swigert et al.,* 2004; *Wilborn et al.*, 2004).

Content of intramuscular fat in pigs is of special importance for acceptability of pig meat. It is known that content of intramuscular fat from 2.5 to 3% is necessary in order for consumers to be satisfied with heat treated pork. In some countries, meat with minimum 4% of fat is more acceptable (*Baltić et al.,* 2010; *Lonergan et al.,* 2007).

Meat pig breeds today usually contain in lean meat less than 1% of fat, and one of the main contributing factors is the genetic basis. For increase of content of fat in muscle tissue, certain pig breeds are crossed in order to increase the content of intramuscular fat. Also, intramuscular fat can be influenced by nutrition. One of the ways to contribute to the increase of intramuscular fat is to decrease the content of protein and/or lysine in pig nutrition. Namely, with the decrease of protein content in grower and finisher diet, the content of intramuscular fat can increase from 13.7 to 176.5%. Similar effect, however more expressed, can be achieved by reduction of lysine content in food, in which case the content of intramuscular fat increases from 66.7 to 136.8% (*Apple,* 2010).

It is obvious that long exposure of pigs to lysine and crude protein deficits has damaging economical effect in fattening and feed conversion, but nutrition with lower content of lysine during the final five to six weeks of fattening in practice has no impact on production performance, and content of fat in meat is still increased. On the other hand, increase of level of crude proteins and/or lysine in diets has always caused the decreased level of fat in pig meat. It was observed that marbling of meat decreased linearly with the increase of lysine content from 0.54 to 1.4% (*Apple,* 2010).

Studies have shown that adding of 2% of leucine into finisher diet for pigs leads to increase of marbling of meat (20 to 30%), without any changes in production results in pig fattening. However, it could be stated that increase of fat content of meat is an indirect response to reduced utilization of lysine due to adding of significant quantities of leucine causing the amino acids misbalance.

Limited intake of food in final stage of fattening has no impact on pH value in muscles, freshness and colour of meat. It was presented in the past that food restriction by 75 to 80% of ad libitum feeding lead to decrease of fat content by 8 to 28%. Interestingly, reduction of the amount of energy in finisher diets causes no changes in fat content of meat, or has impact on any other properties of fresh meat. There is no evidence that choice of cereals/grains used in pig nutrition has any effect on marbling of meat (*Sullivan et al.*, 2007).

Fats and oils have been used for decades to increase the energy value of food for pigs, but the results of their effect on fat content of meat are not consistent. Nutrition based on sunflower or rape seed leads to decrease of content of fat in meat. However, *Apple et al.* (2008) observed that content of fat in meat increased with the increase of share of corn oil in nutrition. Content of fat in meat increased by approx. 25% in pigs fed diets containing 5% of beef tallow. In most studies, importance of the selection of fat and/or oil on marbling of meat has been proven (*Sullivan et al.,* 2007).

Conjugated linoleic acid (CLA) is a mixture of position and geometrical conjugation of linoleic acid isomers. Most of the sources of synthetic CLA contain approx. 65% CLA isomers. From July 2009, CLA is sold in USA under commercial name Lutalin® (BASF SE, Ludwigshafen, Germany). It is used in pig and broiler nutrition. There is reliable data showing that addition of CLA in pig nutrition can influence the increase in meat marbling (*Apple,* 2010).

Derivative of vitamin A – retinoic acid is included in regulation of differentiation and proliferation of adipocytes and in theory its deficit can directly influence the increase of fat content of meat. It is a fact that vitamin A deficit in livestock nutrition can lead to increase of meat marbling, without any influence on production results and carcass quality parameters. *D'Souza et al.* (2000) have also shown that vitamin A deficit during growing stage and final fattening stage leads to increase of fat content in meat by almost 54%. *Olivares et al.* (2009) have recorded that addition of 100,000 IU of vitamin A in nutrition leads to increase of fat content in pork meat from pigs with greater genetic inclination towards higher fat content of meat, but not in case of exceptionally meaty pig genotypes. It was proven that both vitamin A deficit and nutrition rich in vitamin A can con-

tribute to higher content of fat in meat, and consequently better meat marbling. In regard to addition of vitamin A into feeds used in pig nutrition, it should be stated that there are still a lot of uncertainties in regard to the effect of vitamin A on marbling of meat, which is understandable considering the possibility to choose feed, mutual interaction of main components and additives, duration of fattening, etc. (*Dikeman,* 2007).

Nutrition and colour stability of meat and fat

It is expected that change in nutrition which influences the increase of polyunsaturated fatty acids (PUFA) in pig meat also leads to inclination of meat towards the oxidation of fats. Accordingly, great number of researches is directed towards use of antioxidants in nutrition, especially vitamin E, or stimulation of endogenous antioxidant enzymes by adding of minerals (selenium, manganese, magnesium) into feeds (*Marković et al.,* 2008; *Marković et al.,* 2009).

Vitamin E (α-tocopherol) is antioxidant which protects the integrity of the cell membrane and slows done the oxidation of fats, especially during cold storage and/or distribution of meat. Therefore, adding of greater amounts of vitamin E into diets for fatteners maybe is the most studied change in nutrition which can improve the quality of pig meat.

Studies have shown many times that pig nutrition with additional 100 to 200 mg/kg of dl- α-tocopherol acetate can efficiently delay the beginning of the oxidation of fats in fresh pork steaks/cuts and minced meat, as well as partially heat treated or canned pork products. Addition of vitamin E into diets for fattening cattle not only slows down the degree of discoloration, but also improves the colour stability of fresh beef. The effect of increased amounts of vitamin E in pig nutrition, in form of dl-α-tocopherol acetate or natural stereo isomer of d-α-tocopherol acetate, on colour of fresh pig meat or colour stability during cold storage, has not yet been established in numerous studies (*Guo et al.*, 2006; *Marković et al.,* 2008).

Vitamin C has antioxidant properties and usually pigs receive sufficient amounts of this water soluble vitamin from D-glucose in liver. However, addition of ascorbic acid four hours prior to slaughtering leads to forming of dark coloured and intensive red pork meat. However, short term or long term addition of vitamin C has no effect on colour or water binding capacity of pork meat. Also, there is no evidence that addition of vitamin C improves the oxidation stability of meat lipids during storage or distribution, and that in fact pig nutrition which contains large amounts of vitamin C leads to increase of TBARS values of meat during cold storage (*Gebert et al.,* 2006).

Selenium (Se) is a component of endogenous antioxidant enzyme glutathione peroxidase and studies have shown that adding of sodium selenite or selenium from yeasts to pig diet enhanced the activity of glutathione peroxidase in serum. However, increased activity of glutathione peroxidase induced by addition of selenium can be associated with more acceptable colour of fresh meat and better water binding capacity, as well as higher lipid stability during meat storage (*Marković et al.,* 2010). There are, however, different opinions (*Han and Thacker,* 2006).

Manganese (Mn) and magnesium (Mg) are divalent, metal cat ions that can replace each other in several biological functions. However, manganese is necessary for activation of superoxide dismutase, which is included in degradation of superoxide free radicals, so TBARS value in fresh meat steaks/cuts was lower in pigs fed diet containing manganese additive. Also, meat from pigs fed diet supplemented with 350 mg/kg manganese had fewer discolorations from the second to seventh day of storage, compared to meat from pigs fed diets without manganese supplement. Also, addition of manganese in pig nutrition has other advantages because it leads to increase of pH of meat and visual scoring of colour and reduction of L* value of fresh meat colour (*Apple et al.,* 2007).

Sources of fats in pig nutrition and quality of pig fat

Fatty acids in fatty tissue of pigs can be obtained by synthesis from non-lipid substrates or directly by absorption of fatty acids from feeds. So, for instance, glucose obtained by digesting corn and barley increases the share of saturated fatty acids (SFA) in relation to polyunsaturated fatty acids (PUFA), which is not the case when so called oil fractions from concentrated feeds are used in pig nutrition. However, as already mentioned, fat is usually used in pig nutrition, because in this way the energy value of the feed is increased and quantity of cereals/grains (especially corn) used in diets for pigs is reduced (*Lampe et al.,* 2006).

Quality of fats used in pig nutrition depends on many factors, including iodine number, firming point and melting point. Sources of saturated fats, such as tallow and fat, have iodine number from 30 to 70, firming point from 32 to 47°C, and melting point is from 45 to 50°C. Contrary, unsaturated oils obtained from soy bean seed, rape seed, corn, sunflower, safflower, usually have higher iodine number from

100, firming point at temperatures below 30°C and melting point at temperatures of 20°C or below. So, fatty acids composition and quality of fat tissue of pigs depends on the selection of fats, i.e. oils used in pig nutrition (*Apple,* 2010).

Even though there is apparent nutritional value of PUFA in human nutrition, increase of polyunsaturated fatty acids in fatty tissue leads to increase of softness of fat tissue, which can consequently lead to poorer usability in processing and shorter shelf life of products (*Baltić,* 1993). Pig fat with content of linolenic acid (C18:2n-6) over 15% is categorized as soft fat. High content of linolenic acid is consequence of its high content in feeds used in pig nutrition. Soft belly fat leads to difficulties in processing of carcass, decrease of share of fat/bacon, changes in colour and appearance, as well as shorter shelf life. However, most important is that such product is not acceptable for consumers. It has been proven that the thickness and firmness of pig belly increase with the decrease of the iodine number of fats used in their nutrition. Nutrition using animal fats does not lead to incidence of soft pig belly, as in case of fats of plant origin used in pig nutrition. It is interesting that the fat/bacon of pigs fed sunflower, safflower and rape seed were scored significantly lower in sensory analysis of freshness, tenderness, amount of salt, odour and taste and general acceptability, compared to fat/bacon from pigs fed diets containing tallow. It was observed that fat/bacon from pigs fed diets containing soy bean oil is softer and of lower quality (*Teye et al.*, 2006).

There is growing evidence that between 50 and 60% of changes of fatty acid composition of pig fat is induced by type of fat used in nutrition. Changes of the fatty acid composition occur during first 14 to 35 days of nutrition with specific fats, while later the changes decrease. It has been proven that fatty acid composition of meat fat and subcutaneous fat tissue in pigs changes significantly to 17,4 kg of body weight, so during the first stage of pig nutrition with 5% of soy bean oil, iodine number of pig fat increases by 12 (*Apple et al.*, 2007). It is known that the time of semi-degradation of linoleic acid (C18:3n-3) of subcutaneous fatty tissue is 300 days. So, economic benefits when traditional food contains high level of fats, associated with increased level of utilization during growing stage of pigs, can cause low quality of pig fat. It is uncertain if removal of all fats from the final stage of pig nutrition or replacement of unsaturated fatty acids with tallow or hydrogenized fats will have consequences on quality of pig fat (*Apple et al.*, 2007).

Conclusion

The quality of meat depends on numerous factors. The attention is most often focused on the effect on nutrition on meat quality, i.e. pH value, tenderness, marbling, quality of fat, sustainability, sensory properties. Of many nutrition factors, mainly commented are the effect of pre-slaughter starvation on meat quality, restricted feeding, compensatory feeding, content of protein and content of lysine in feeds and adding of vitamin E. Studies in this field are numerous and complex, considering that in addition to feeding/nutrition they include the effect of other factors (genetic basis, pre-slaughter handling of animals, etc.) which have considerable impact on meat quality. Also, inevitable economic effects, as well as interest of all stakeholders that consumers are satisfied with the quality of meat, should also be considered.

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Ishrana i kvalitet mesa

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R e z i m e: Brojni su činioci koji utiču na kvalitet mesa svinja (genetska osnova, uslovi gajenja, postupci pre klanja, klanje, obrada trupa, hlađenje). Razume se da je ishrana jedan od veoma značajnih činilaca koji utiče i na količinu i na kvalitet mesa. Osnovni cilj pravilne ishrane je što je moguće više iskorišćavanje genetskog potencijala svinja, i dobijanje mesa koje će zadovoljiti potrošača ili naći svoju namenu u izradi proizvoda od mesa. Kvalitet svinjskog mesa se najčešće vezuje za pH vrednost, boju, sočnost, mekoću, sadržaj intramuskularne masti (mramoriranost), održivost i, uopšte, za prihvatljivost od strane potrošača. U ovom radu prikazan je uticaj određenih modifikacija u ishrani svinja na postmortalne promene, odabrane tehnološke osobine mesa (pH vrednost, sposobnost vezivanja vode, boja), sadržaj intramuskularne masti, kvalitet masti i prihvatljivost mesa.

Ključne reči: *svinjsko meso, ishrana, kvalitet.*

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