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Effect of quantum therapy on pork quality

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Abstract: In this study the impact of quantum therapy on meat quality of slaughtered pigs was investigated. For this purpose the pigs were treated with different doses of magnet-infrared-laser (MIL) radiation. Animals were divided into four groups according to radiation doses (4096, 512, and 64 Hz, and control without application), which were applied in the lumbar area of *musculus longissimus dorsi* (loin) at various time intervals prior to the slaughter (14 d, 24 h, and 1 h). Animals were slaughtered and the meat quality was evaluated by determining of pH value (1, 3, and 24 h post slaughter), drip loss, colour, and lactic acid and phosphoric acid amounts. MIL therapy can be used in various fields of veterinary medicine as are surgery and orthopaedics, internal medicine, dentistry, pulmonology, gastroenterology, gynaecology, urology, nephrology, and dermatology. The results achieved showed that MIL radiation used in a short period before slaughter (1 h) can cause a change in the meat quality, as reflected by the non-standard development of pH values, increases in drip loss, and changes of meat colour.

Key words: Quantum therapy, Meat quality, Colour, Drip loss, Lactic acid, pH
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1 Introduction

Quantum therapy in veterinary medicine is a new direction, which began to develop in the 90s of the 20th century together with the production of portable semiconductor laser apparatus. A wide range of therapeutic effects are explained by biological activation in the tissues after laser radiation exposure on animals. Unlike medication, therapy laser radiation is reflected as special effects and the animal's body responds by increasing the non-specific immunity (Kataranov *et al.*, 2003). Recently, new physical methods (such as acupuncture, high-frequency therapy, and low level laser therapy) in the therapy of animals were discovered. They are ecological and safe without by-product and metabolites. According to the results of the scientific work of many authors, the laser therapy appears to be most economical, simple, and effective in the treatment of animals (Kazeev, 1995).

The phenomenon of laser biostimulation (LBS) is extensively used in medical practice, although its nature and mechanisms are far from being elucidated and understood (Tsyba and Kaplan, 1991). Major properties of LBS and results of studies of laser radiation interaction with biologic objects may be summed as follows:

1. Selectivity of laser treatment: changes are induced in "ill" biosystems, while there is no effect on "healthy cells";

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2. Treatment effects are different in vivo and in vitro;

3. LBS effects are seen in non-cellular objects like plant pollen;

4. The stimulation effect has not been found during irradiation with white light;

5. Therapeutic effects of LBS are practically identical for laser radiation with any wavelength in the range of 0.4 to 1.5 μm;

6. Protein molecules do not have in vitro absorption bands for radiation in the wavelength range of 0.4 to 1.5 μm;

7. LBS effects are seen during the use of 1.5 mW/cm^2 or lower intensities and of low-energy doses calculated even without accounting for reflected light or light that has travelled through a phase object. LBS effects reported in medical practice include a decrease in blood viscosity, stimulation of microcirculation, pain relief, enhancement of motility of cell receptors and some cells (e.g., sperm cells), stimulation of the immune and nervous systems.

The use of magnet-infrared-laser (MIL) therapy principles for therapeutic, prophylactic, and regenerative purposes in clinical practice of veterinary medicine as a new physical therapy raises the question of withdrawal period and the possibility of qualitative meat changes [pale, soft, exudative (PSE); dark, firm and dry (DFD)] in slaughtered animals that have been therapeutically treated before slaughter. The use of MIL therapy principles in veterinary medicine is gaining importance due to the increasing number of veterinarians who use laser devices.

Due to the fact that laser devices are used for therapeutic, prophylactic, and regenerative purposes in animals which are intended for slaughter, the aim of the study was focused on the evaluation of MIL radiation impact on meat quality.

2 Materials and methods

Low-energy quantum therapy is defined as a therapy in which light energy is absorbed by part of the body and the temperature is not increased more than 1 °C. The most common are low-energy devices (LED) operating on semiconductor lasers (Damirov, 2001). The RIKTA device (Type 04/4-MV, Milta PKP-GIT, Russia) was used in the experiment. The MIL therapeutic device RIKTA combines pulse laser radiation (0.89 mm), continuous monochromatic infrared radiation (0.85 to 0.89 mm), red LED light (0.65 mm), and a static magnetic field with induction of 35 mT. RIKTA device operates in pulse mode (5, 50, and 1000 Hz of pulse frequency) with an output power not less than 8 W.

2.1 Application of MIL radiation in pigs

MIL radiation (the device RIKTA 04/4-MV), to breed Landrace pigs (n=36) with an average weight of 120 kg, was applied. According to Munk (2007), the portion of genotype and alleles of *RYR1* gene in the Landrase breed in Slovakia was 64.28%. The application was performed with terminal device (emitting block) with 100% power (20 W) in the lumbar region of the *musculus longissimus dorsi* (loin) on both halves, and with different doses: 4096, 512, and 64 Hz, respectively, for 5 min, and control without application of MIL radiation (n=3 each group) at various time intervals prior to the slaughter (14 d, 24 h, and 1 h).

2.2 Slaughtering and sampling

The pigs were slaughtered in a slaughterhouse MABIT Ltd., Zemplínska Teplica, Slovakia. Duration of the transportation to the slaughterhouse was less than 2 h, animals were slaughtered immediately without resting, and they were stunned using electrical current (50 Hz, 1.3 A, 4 s). The carcasses were chilled at 2 °C with an air velocity 1–2 m/s. pH values were measured directly in the carcass, with the muscle samples for the analysis (drip loss, colour and lactic acid and phosphoric acid) being taken from region of the *M. longissimus dorsi* 1 h after slaughtering.

2.3 Determination of meat quality

Meat quality was evaluated by determining of pH value, drip loss, colour, and lactic acid and phosphoric acid amounts.

The pH of the meat was measured by a digital pH meter with glass electrode (AMA digit, Model AD 140, Amarell Electronic, Germany). The pH values were measured directly in the carcasses (*M. longissimus dorsi*, after last rib) after slaughtering the animals at 1, 3, and 24 h post slaughter.

The drip loss was determined by a bag method according to Honikel (1987), and was recorded as a drip loss after 24 h storage at 4 °C.

Spectrophotometric determination of meat colour (percentage of remission) was determined by use of a spectrophotometer (at 520 nm) with an adapter (Spekol 11, Carl Zeiss Jena, Germany). Determination was carried out on the fresh slice of muscles taken from *M. longissimus dorsi*.

The measurement of lactic and phosphoric acids was performed in the meat samples taken 1 h after slaughtering, which were processed immediately (homogenization in the water) and then determined by use of an electrophoretic analyzer (Type EA 102) with a conductive detector (Villa Labeco, Spišská Nová Ves, the Slovak Republic) (Koréneková *et al.*, 2009). The results of analysis were evaluated using a computer programme ITPP pro 32.

2.4 Statistical evaluation

The mean values and standard deviations (SDs) were calculated by using column statistics to process six values for each analyzed group. Statistically significant differences between groups for each quality parameter were calculated using one-way analysis of variance (ANOVA) by way of Tukey's comparative test performed in the program GraphPad Prism 5. Statistical significance was evaluated as significant if P value was <0.05.

3 Results

3.1 Application of MIL radiation 14 d before slaughter

After application of MIL radiation 14 d before slaughter pH values were measured 1, 3, and 24 h after slaughter (Table 1). Statistically significant differences were found in the pH values 3 h after slaughter (pH_3) between the 64 Hz and control groups ($P<0.05$), where the control group had higher mean pH value than the irradiated group of 64 Hz.

Drip loss and colour of meat were measured in *M. longissimus dorsi* taken 1 h after slaughtering (Table 2). The meat colour was lighter in the groups of 512 Hz and control, compared with the groups of 4096 and 64 Hz, with statistically significant differences ($P<0.05$).

Comparing the concentrations of lactic and phosphoric acids in the experimental and control groups (Table 3), no statistically significant differences were found.

3.2 Application of MIL radiation 24 h before slaughter

After application of MIL radiation 24 h before slaughter, the pH values (1, 3, and 24 h after slaughter), drip loss, meat colour, and lactic and phosphoric acid amounts were measured directly in the carcasses (*M. longissimus dorsi*, after last rib). By comparing the pH values, drip loss and colour of meat, and the concentrations of lactic and phosphoric acids between the experimental and control groups, no statistically significant differences were found (Tables 1, 2 and 3).

3.3 Application of MIL radiation 1 h before slaughter

After application of MIL radiation 1 h before slaughter, the pH values were measured 1, 3, and 24 h after slaughter directly in the carcasses (*M. longissimus dorsi*, after last rib), as shown in Table 1. Statistically significant differences were found between the values of pH 1 h after slaughter (pH_1) in the group irradiated with 4096 Hz, as well as 512 Hz, compared to the control group and the group irradiated with 64 Hz ($P<0.05$).

Drip loss and colour of meat were measured in *M. longissimus dorsi* taken 1 h after slaughtering (Table 2). Statistically significant differences were found in the drip loss between the group radiated with of 512 Hz and the control group ($P<0.05$), with the highest loss in the 512 Hz group. Statistically significant differences in the meat colour were found between the control and 64 Hz groups and the 4096 and 512 Hz groups ($P<0.05$), with the colour was lighter in the latter. Comparing the concentrations of lactic acid and phosphoric acid in the experimental and control groups (Table 3), statistically significant differences were found in values of phosphoric acid, with the concentration in the control group was significantly lower than that in the 4096 Hz group ($P<0.05$).

3.4 Overall impact assessment of MIL radiation on meat quality of pigs

The highest mean pH_1 values were measured in the control samples. Extremely low average pH_1 values were found after application of MIL radiation doses with 4096 and 512 Hz for 1 h prior to slaughter.

Table 1 Effect of MIL radiation on pH values 1, 3, and 24 h after slaughter

Exposure of MIL radiation	pH								
	14 d before slaughter			24 h before slaughter			1 h before slaughter		
	1 h after slaughter	3 h after slaughter	24 h after slaughter	1 h after slaughter	3 h after slaughter	24 h after slaughter	1 h after slaughter	3 h after slaughter	24 h after slaughter
4096 Hz, 5 min	5.30 (0.035)	5.53[ab] (0.016)	5.67 (0.048)	5.33 (0.161)	5.46 (0.008)	5.63 (0.023)	4.83[b] (0.322)	4.95 (0.313)	5.65 (0.322)
512 Hz, 5 min	5.37 (0.062)	5.57[ab] (0.015)	5.76 (0.082)	5.32 (0.029)	5.50 (0.015)	5.68 (0.110)	4.78[b] (0.306)	4.94 (0.304)	5.61 (0.332)
64 Hz, 5 min	5.31 (0.045)	5.51[a] (0.030)	5.75 (0.039)	5.29 (0.045)	5.54 (0.175)	5.62 (0.035)	5.33[a] (0.052)	5.24 (0.049)	5.78 (0.090)
Control	5.39 (0.110)	5.63[b] (0.121)	5.77 (0.149)	5.32 (0.030)	5.53 (0.037)	5.68 (0.091)	5.49[a] (0.053)	5.13 (0.052)	5.63 (0.092)

Data are expressed as mean (SD). Values with different superscript letters are significantly different ($P<0.05$)

Table 2 Effect of MIL radiation on drip loss and colour of meat

Exposure of MIL radiation	Drip loss (%)			Colour (% remission)		
	14 d before slaughter	24 h before slaughter	1 h before slaughter	14 d before slaughter	24 h before slaughter	1 h before slaughter
4096 Hz, 5 min	4.478 (1.999)	3.430 (3.078)	6.753[ab] (2.700)	22.867[a] (2.171)	20.939 (3.960)	31.100[a] (2.488)
512 Hz, 5 min	5.363 (1.140)	7.085 (4.084)	7.750[a] (2.716)	15.821[b] (1.098)	14.629 (1.852)	29.300[a] (1.638)
64 Hz, 5 min	4.137 (2.569)	2.565 (1.073)	4.047[ab] (2.114)	25.696[a] (4.205)	19.230 (1.639)	18.330[b] (1.639)
Control	3.470 (2.565)	7.585 (3.895)	3.587[b] (2.540)	17.203[b] (2.861)	20.751 (5.394)	18.260[b] (1.621)

Data are expressed as mean (SD). Values with different superscript letters are significantly different ($P<0.05$)

Table 3 Effect of MIL radiation on lactic acid and phosphoric acid concentrations

Exposure of MIL radiation	Lactic acid (g/100 g meat)			Phosphoric acid (g/100 g meat)		
	14 d before slaughter	24 h before slaughter	1 h before slaughter	14 d before slaughter	24 h before slaughter	1 h before slaughter
4096 Hz, 5 min	1.460 (0.312)	1.347 (0.112)	1.456 (0.183)	0.365 (0.073)	0.446 (0.023)	0.605[a] (0.092)
512 Hz, 5 min	1.504 (0.367)	1.494 (0.144)	1.520 (0.170)	0.414 (0.037)	0.502 (0.097)	0.486[ab] (0.023)
64 Hz, 5 min	1.692 (0.113)	1.465 (0.252)	1.214 (0.209)	0.432 (0.077)	0.507 (0.039)	0.550[ab] (0.097)
Control	1.367 (0.177)	1.274 (0.209)	1.226 (0.200)	0.432 (0.085)	0.497 (0.062)	0.477[b] (0.062)

Data are expressed as mean (SD). Values with different superscript letters are significantly different ($P<0.05$)

The MIL radiation 1 h prior to slaughter at higher doses (512 and 4096 Hz) also had a negative impact on the drip loss. Application of these doses affected the colour of meat as assessed by measuring the percentage of remission; the highest percentage of remission was measured in muscle samples from the pigs slaughtered 1 h after application. The highest mean concentration of lactic acid was found in muscle samples from the pigs administered with dose 64 Hz 14 d before slaughter. After administration of high doses of MIL radiation (4096 Hz), the highest mean value of phosphoric acid was found in samples of lean pigs in which MIL radiation was administered 1 h prior to slaughter.

4 Discussion

Medical devices based on semiconductor lasers have found a wide application in modern medical practice (Isaev, 2001). MIL therapy provides an ecologically clean, no-invasive, non-medicamental, and highly-effective treatment and prevention options for a wide range of diseases. The main point of MIL therapy is the combined potentiated influence of impulse infrared laser irradiation, pulsating wide-band infrared irradiation, pulsating red light, and constant magnetic field upon the biological structures of an object (e.g., a patient, an animal, a plant). Impulse infrared laser irradiation deeply penetrates tissues up to 10–13 cm, exerts a powerful stimulating influence upon blood circulation and membrane cellular metabolism, and activates neurohumoral factors and immunocompetent systems, while harmonising hormonal factors of metabolism (Joint Stock Company "United Space Device Corporation"; www.milta-f.com). The effects of different doses of MIL radiation on meat quality (pH, drip loss, meat colour, and lactic acid and phosphoric acid contents) were evaluated.

The meat of slaughtered animals is a complex and dynamic biological system, which involves a series of postmortem biochemical processes. Postmortem processes are initiated at the time of slaughter, and include a set of biochemical changes and processes by which the muscle is transformed into a meat (Ingr, 1995).

Changes of the basic characteristics of meat quality, which occur in the tissue after slaughter, have a considerable impact on its further use in food processing. One of the reasons for these changes (apart from the slaughter method or the treatment of the carcasses after the slaughter) is metabolism of the carbohydrates in the muscle tissue, and the muscle glycogen in particular. Postmortem anaerobic glycolysis leads to the accumulation of the lactate in the muscles. If lactate levels are too high, PSE or acidic meat can result (Sieczkowska *et al.*, 2010).

Extreme progression in pH during the conversion of muscle to meat has long been known to influence the colour characteristics of pork, and has in fact provided the basis for two of the most well-known inferior meat quality grades, namely DFD or PSE meat (Lindahl *et al.*, 2006). In living animals, the acidification of muscles causes pain and distress and can result in a reduction in life quality. Present knowledge of the cardio-respiratory capacity of meat animals, especially modern pigs and poultry, is insufficient. This, together with glycogen and the anaerobic end product of its metabolism, lactate, has a strong influence on the welfare of animals and meat quality (Pösö and Puolanne, 2005).

Application of MIL radiation affected the value of pH_1 in pigs that were killed 1 h after application. The pH_1 values were extremely low, especially in animals that were treated with radiations 4096 and 512 Hz (4.83 and 4.78, respectively). Normal pH_1 value is greater than 5.80 and less than 6.20 (Ingr, 1995). The PSE meat is characterized by a pH_1 value lower than 5.8 and DFD meat is characterized by a pH value 24 h after slaughter (pH_{24}) greater than 6.20 (Ingr, 1995).

After slaughtering animals, pH value is affected first by H_2CO_3, which cannot be removed postmortem by blood vessels and collects in the muscles. Together with lactic acid and phosphoric acid, a decrease in pH value occurs. The relationship between initial the glycogen content and the final pH is linear only at very low levels of glycogen (Purchas and Aungsupakorn, 1993). Przybylski *et al.* (1994) stated that in most muscles, ultimate pH decreases following a curvilinear regression when glycolytic potential increases, until a plateau value dependent on the animal species and muscles. The glycolytic potential corresponding to the convergence point between the quadratic part of the curve and plateau depends also on the animal species and muscles.

Water is the main component of the meat, and lean muscle contains up to 75%. The water is bound in muscle tissues by different ways and different power. The most strongly bound hydrating water and other water proportions are immobilized between the individual structural parts of the muscle, while the rest is able to move freely in the intercellular spaces. It was shown that 70% of the total water content in the muscle is contained within myofibrils, 20% within sarcoplasma, and the remaining 10% within the intercellular space (Pipek, 1997).

Drip loss is of high importance in pig meat production due to its financial implications. The meat processing industry is particularly affected because a low water-holding capacity limits the yield in further processing. In general, meat with a high drip loss has an unattractive appearance and therefore has a low consumer acceptance, which leads to loss of sales (Otto *et al*., 2004). Water is lost after the slaughter as a drip during carcase chilling or during the cold meat display (Forrest *et al*., 2000). The pH value is known to be negatively related to drip loss but the magnitude of correlation differs between studies (Otto *et al*., 2004). Application of MIL radiation to pigs caused increased levels of water loss in the muscle samples from animals that were treated by doses 512 and 4096 Hz compared to control samples irradiated 1 h before slaughter, which is closely related to very low pH_1 values.

The total concentrations of myoglobin and its derivative type, together with properties that affect light scattering, determine the colour of meat. Deoxymyoglobin is a pigment that provides the colour typical of the freshly-cut muscle. After exposure to atmospheric oxygen, oxygenation proceeds and produces a bright red oxymyoglobin. After a long period of storage, oxymyoglobin oxidizes to an unattractive brown metmyoglobin, in which oxygen is replaced by a water molecule (Musilová and Dvořák, 2001).

Stress before slaughter acts secondary so that may lead to the appearance of meat with abnormally high or abnormally low pH value, and it is known that pH can affect the colour of the meat in two ways. Mitochondrial activity in postmortem muscles is increased by high storage temperature and high pH values (above 6.0) in comparison to normal meat with a pH of approximately 5.6 (Cheah and Cheah, 1971; Bendall, 1972; Bendall and Taylor, 1972). Meat with high pH value has a high water-binding capacity associated with a higher absorption of light, so the meat remains translucent (appears darker). Contrarily, very rapid lactate production with a high temperature affects the value of protein denaturation, increases the light scattering in the muscle, and causes brightness of PSE meat (Ingr, 1995).

The meat colour is an important quality parameter monitored by consumers when selecting meat in retail and is in relationship with hem pigments, particularly myoglobin, but also hemoglobin. The higher content of hem pigments causes lower lightness and the meat is darker, redder. Factors affecting meat colour can be divided into internal and external factors. The internal factors are primarily animal species, but also age, muscle type, the degree of postmortem glycolysis, intramuscular fat content, the amount of pigments, and their oxidation state. The external factors may include animal husbandry, nutrition, preslaughter handling, stunning and bleeding, cooling, packaging, distribution, and sale conditions (Šimek and Steinhauser, 2001).

Individual animal species have different chemical compositions of carcass tissues, including the hem pigments in the meat. The colour is different even within an animal species. This is due to a number of intravital factors affecting the animal during its life, but also technological influences during slaughter, dressing, and cutting. Pork from young animals is light-red to pink-red with a whitish gray tint. Older animals have dark red colour of meat. The meat colour affected by pre-slaughter handling and stunning is related to PSE and DFD changes. It is well known that these defects are accompanied by colour changes (paler, gray-reddish) in pork (Šimek and Steinhauser, 2001).

Meat colour (reported as percentage of remission) was affected by the application of MIL radiation mainly in pigs, which were treated by doses of 4096 and 512 Hz 1 h prior to slaughter (the highest percentage of remission). According to Lindahl *et al*. (2006), redness of pork is closely related to the extent of heat generation, keratin phosphate and ATP levels, and pH of the muscle immediately postmortem.

Conversion of glycogen to lactic acid takes place through the change of organic compound-containing phosphorus [adenosine triphosphate (ATP)]; its quantity is reduced after slaughter. Phosphoric acid is formed during energy metabolism when ATP is degraded to adenosine diphosphate (ADP) by the enzyme ATPase and inorganic phosphate and energy is released. Phosphorylation of ADP results in regeneration of ATP. Creatine phosphate is needed for this regeneration. After depletion of creatine phosphate, ADP is degraded to adenosine monophosphate (AMP) which is converted irreversibly to inosine monophosphate (IMP) by means of the enzyme AMP deaminase (Šimek *et al*., 2002). The amount of glycogen in the muscle tissue depends on the species and muscle type (Przybylski *et al*., 1994). Glycogen breakdown plays a major role in changes occurring in the muscle tissue postmortem and has a considerable effect on meat quality (Przybylski *et al*., 2006).

Statistically significant differences between the lactic acid values in the muscle tissues were not found, but significant differences were found in the phosphoric acid values in the group that was treated by a dose of 4096 Hz 1 h prior to slaughter. During the process of muscle aging, the muscle is subjected to a series of biochemical changes and is transformed to the meat. These changes improve organoleptic and technological properties of meat to protect against microorganisms, and thereby extend meat shelf-life. The most important biochemical changes in the muscles after slaughter are degradation of glycogen and energy-rich phosphates, resulting in the formation of lactic acid, phosphoric acid, and the related change in pH. Meat aging is a long biochemical process that occurs after the slaughtering of animals, and includes the continuation of the anaerobic enzymatic activity of the muscle as muscle is transformed to meat. Metabolic product in the aging process remains in the muscle and contributes to organoleptic characteristics of the meat (Čuboň *et al*., 2004).

It is mainly lactic acid and phosphoric acid or other acids that cause a reduction in pH (Šimek *et al*., 2002). The pH of the meat is affected not only by the levels of lactic acid, but also by phosphoric acid and other acids (Puolanne and Kivikari, 2000; Šimek *et al*., 2003). Lactic acid is generated as a product of biochemical changes during postmortem changes in the meat. It is an indicator of typical or atypical aging processes of the meat. Dynamics of lactic acid during the process of meat aging reflects the quantitative transformation of glycogen to lactic acid (Koréneková and Turek, 2008).

5 Conclusions

According to the available literature sources and practical experiences, MIL therapy can be used in various fields of veterinary medicine (surgery and orthopaedics, internal medicine, dentistry, pulmonology, gastroenterology, gynaecology, urology, nephrology, and dermatology). The results obtained confirm that the method of therapy used mainly in a short period before slaughter (1 h) may cause changes in meat quality reflected by the development of non-standard pH values, increased water loss, and a change in meat colour.

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