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THE EFFECT OF DIETARY MAGNESIUM OXIDE SUPPLEMENTATION ON CARCASS VALUE, MEAT QUALITY AND MUSCLE LACTATE AND GLYCOGEN LEVEL OF PIGS

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ABSTRACT

The objective was to study the effect of dietary magnesium oxide supplementation (MgO) on glycogen and lactate level in muscle post mortem and on carcass and pork quality traits. Twenty four crossbred (Large White x White Meaty)x(Pietrain x Hampshire) barrows and gilts were tested by DNA probe on malignant hyperthermia (MH) and equal heterozygotes (n=12) and normal on MH (n=12) pigs were taken in experiment. Dietary MgO supplementation (3.6 g additional magnesium per pig for 5 days prior to slaughter) increased plasma magnesium level ($P<0.05$). Supplemented magnesium had no effect on carcass traits. Also difference in intramuscular fat in musculus longissimus dorsi (LD) was not significant ($P>0.05$) between control and magnesium supplemented pigs. Comparison of meat quality traits indicates that MgO supplementation to pigs raised the pH in the LD muscle at 45 min after slaughter and significant differences ($P<0.05$) were found between homozygotes and heterozygotes pigs. Pigs fed the MgO supplemented diet had lower ($P<0.05$) percentage of drip loss in both normal and heterozygotes compared to control heterozygotes pigs. Significant differences were found in glycogen and lactate levels in LD between heterozygotes control group and normal MgO supplemented pigs.

Key words: pig, magnesium, carcass and meat quality, glycogen, lactate

INTRODUCTION

Pork with low water-holding capacity continues to be a problem even in malignant hyperthermia (MH) gene – normal populations (Cheah et al., 1998). Preslaughter handling of pigs can influence pork quality and acute stress before slaughter can lead to PSE (pale, soft, exudative) or RSE (redish, soft, exudative) meat by stimulating the rate of immediate postmortem acidification, increasing lactate, decreasing muscle glycogen and lowering water-holding capacity (Warriss, 1993).

The primary effect of magnesium appears to be a reduction in neuromuscular stimulation due to calcium antagonist effects of the cation (Kietzman and Jablonski, 1985). However, considerable variation in stress reduction is reported in studies depending on such factors as route of administration, dose and timing.

Dietary magnesium supplementation of pigs has reduced the effect of stress by decreasing plasma cortisol and catecholamine concentrations (Kietzman and Jablonski, 1985) and have been shown a viable option for improving meat quality (Schaefer et al., 1993). D'Souza et al. (1998) supplemented finishing swine diets with magnesium-aspartate hydrochloride for 5 days prior to slaughter and reported reduced drip loss and reduction in the incidence of PSE pork. Research has shown that Mg-supplementation (alone) may have benefitial effects on the behavior (Kuhn et al., 1981), stress response (Kaemmerer, Kietzmann, 1984, Ludvigsen, 1985, D'Souza et al., 1998) and meat quality (Schaefer et al., 1993, D'Souza et al., 1999) of swine. Recently published data (Hamilton et al., 2002) suggest an inconsistent effect of short-term feeding of magnesium sulfate on muscle colour and drip loss in pigs with both low (normal) and high GP (glycolytic potential).

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It seems further research is needed to clearly establish the impact of level, time and source of supplementary magnesium on important meat quality traits.

MATERIAL AND METHODS

Animals and diets

A total of 24 pigs were used in the study. Pigs were the progeny of crossbred sires (Pietrain x Hampshire tested by DNA probe as heterozygotes on malignant hyperthermia - MH) mated to dams (Large White x White Meaty tested as homozygote negatives on MH). Barrows and gilts were balanced and tested by DNA probe (Fujii et al., 1991, Lahučký et al., 1997). Equal heterozygotes (n = 12) and normal on MH (n = 12) pigs were taken in experiment. At 80 ± 5 kg live weight heterozygote pigs were tested using biopsy instrument (Biotech, Slovakia) on meat quality prediction (pH from bioptate after 1 hour incubation at 39 OC) as was described earlier (Lahucky et al., 2000). No significant differences in pH bioptate values were found between control (n = 6) and Mg supplemented heterozygous pigs (n = 6), (6.14 ± 0.11 vs. 6.12 ± 0.10). Pigs were devided into two groups consisted of 12 pigs each (6 heterozygotes – HT and 6 normal, homozygotes – HM). Animals were housed in control station of RIAP Nitra and penned in pairs. They were fed with commercial feed mixture (table 1) ad libitum and had free access to water via a nipple drinker. Pigs in the control diet were fed 3 kg of finisher feed per pig per day for 5 days prior to the slaughter. Pigs in Mg-diet treatment were fed 3 kg of the same feed supplemented with Magnesium Oxide (MgO, Biofactory, Slovakia) at level to supply 3.6 g additional magnesium per pig per day for 5 days prior to the slaughter.

Table 1: Formulation and nutritive value of finisher diet

Ingredients	%
Barley	42.7
Wheat	21.0
Oat	15.0
Soybean meal	12.0
Wheat brans	2.0
Meat and bone meal	2.0
Fodder yeast	1.7
Mineral supplement	2.5
Biofactor supplement	0.6
Fodder salt	0.5
Dry matter	86.30
Crude protein	16.84
Crude fat	2.43
Crude fibre	4.86
N-free extract	41.68
Metabolizable energy (MJ)	12.31
Lysine	0.86
Calcium	0.96
Phosphorus	0.71
Magnesium	0.22

Slaughter and sample collection

The animals were killed at 105 (± 5) kg live weight by electro stunning (90-100 V, 0.9-1.0 Amps, 50 Hz, application time 5-7 s), afterwards were exsanguinated and scalded (10 min, 62 ^{0}C). Evisceration was completed about 20 min post mortem. Chilling of the carcasses (air temperature 4 to 2 ^{0}C cycle, air velocity 0.5-1.0 m/s) started approximately at 70 min post mortem and was continuing overnight.

Blood samples (4 ml) were collected at the time of exsanguination in blood collection tubes to determine calcium and magnesium concentrations. Approximately 0.8 g muscle was collected from m. longissimus dorsi (LD) by biopsy instrument between 13th and 14th rib at 0 (immediately after exsanguination), 15 and 45 min. Muscle samples were frozen and stored at -4 ^{0}C before analysing.

Biochemical analysis and pork quality measurements

Plasma and feed magnesium concentrations were determined using atomic absorption spectrophotometry (Unicam).

Muscle glycogen concentrations were determined by the colorimetric method described by Dreiling et al. (1987). Muscle lactate was determined by isotachophoretic technique described earlier (Lahucky et al., 1995).

At 45 min after slaughter the pH (portable pH meter, model 3071, Jenway, England) was directly determined in the m. longissimus dorsi (13/14 rib) using a combined glass electrode (P19/BNC). The day after slaughter (24 h) conductivity (Tecpro GmbH, Germany), colour (CIE Lab, Miniscan, Lightness) and drip loss (Honikel, 1998) were also measured. Analysis of intramuscular fat was done by Infratec (Germany).

Calculation and statistical analyses

Statistical significance between control and Mg supplemented groups and between genotypes of pigs on regard RYR1 gene was evaluated using Student´s test.

RESULTS AND DISCUSSION

Plasma calcium and magnesium concentrations are presented in Table 2. There were no differences (P>0.05) in plasma calcium concentrations between the dietary treatments. Plasma magnesium concentration was higher (P<0.05) in pigs fed the MgO supplemented diet than in pigs fed the control diet. Increasing in plasma magnesium concentration in pigs fed the diet supplemented with MgO in this experiment (10%) was comparable with results introduced by D'Souza et al. (1999), but was lower than that observed by Schaefer et al. (1993) (14%) using magnesium aspartate at a rate of 20 g per day per pig.

The effect of MgO supplementation on carcass characteristics is presented in Table 3. Carcass weight, dressing percentage and another carcass traits were unaffected (P>0.05) by supplementing with MgO what is comparable with results introduced by Kuhn et al. (1981), Schaefer et al. (1993) and Hamilton et al. (2002) in pigs and in lambs (Apple et al., 2001). The differences in live weight between control HT and MgO normal pigs were due to earlier date of slaughter of pigs fed MgO supplemented diet. The observed higher level of intramuscular fat in pigs supplemented with MgO is non-significant (P>0.05) and also Schaefer et al. (1993) reported that intramuscular fat content and marbling score (Apple et al., 2001) were not affected by supplementing swine diets with Mg.

Table 2.: The effect of dietary magnesium oxide (MgO) supplementation on plasma calcium and magnesium concentration at slaughter

Trait	Control		MgO		Significance
	Mean	S.D.	Mean	S.D.	
Calcium, mg/L	24.9	1.27	24.6	1.06	-
Magnesium, mg/L	8.5	1.02	9.4	0.96	+

+P<0.05

Table 3.: The effect of dietary magnesium oxide (MgO) supplementation on carcass value and intramuscular fat content

Trait		Control		MgO		Significance
		HT	HM	HT	HM	
Live weight, kg	Mean	106.14a	103.29	104.20	98.60b	+
	S.D.	7.41	6.34	4.45	1.20	
Half carcass, kg	Mean	42.05	41.24	41.95	39.56	-
	S.D.	3.45	3.15	1.99	1.04	
Dressing percentage, %	Mean	81.27	81.08	81.38	81.14	-
	S.D.	0.47	0.76	0.28	0.46	
Loin eye area, cm2	Mean	42.29	42.29	47.80	42.20	-
	S.D.	3.06	3.77	7.30	3.49	
Backfat thickness, cm	Mean	2.84	2.62	2.89	2.54	-
	S.D.	0.27	0.25	0.53	0.19	
Valuable meaty cuts, %	Mean	51.69	50.90	52.39	50.97	-
	S.D.	1.09	1.53	3.13	2.41	
Intramuscular fat, %	Mean	2.41	2.59	3.06	2.54	-
	S.D.	0.45	0.58	1.36	0.49	

+P<0.05

Table 4: The effect of dietary magnesium oxide (MgO) supplementation on meat quality traits of longissimus dorsi muscle

Trait		Control		MgO		Significance
		HT	HM	HT	HM	
pH 45 min	Mean	6.19a	6.47b	6.42b	6.71c	+
	S.D.	0.04	0.06	0.16	0.05	
Conductivity 24 h, mS	Mean	5.93	4.52	5.10	4.95	-
	S.D.	1.67	0.62	0.17	0.96	
Lightness (L) 24 h	Mean	49.13	49.06	48.32	48.34	-
	S.D.	3.86	2.62	2.58	2.78	
Drip loss 24 h, %	Mean	6.12a	4.75b	5.02b	3.85b	+
	S.D.	0.98	0.77	0.51	1.06	

+P<0.05

Table 5: The effect of dietary magnesium oxide (MgO) supplementation on glycogen and lactate levels in longissimus dorsi muscle

Trait		Control		MgO		Significance
		HT	HM	HT	HM	
Glycogen 30 min	Mean	46.88a	49.90	49.32	51.76	+
	S.D.	4.41	5.12	11.15	3.96	
Lactate 30 min	Mean	46.92a	39.63	41.83	39.00b	+
	S.D.	6.28	7.47	5.62	3.98	
Glycogen 24 h	Mean	7.94	8.92	8.39	9.71	-
	S.D.	0.86	1.66	1.18	0.86	
Lactate 24 h	Mean	88.68	78.60	81.82	76.13	-
	S.D.	13.08	13.51	12.10	5.50	

+P<0.05

Muscle pH and meat quality results are shown in Table 4. Pigs fed the MgO supplemented diet had higher muscle pH compared to pigs fed the control diet. Significant differences (P<0.05) we received between control heterozygotes pigs and both MgO normal and heterozygotes pigs. D'Souza et al. (1998) found higher (P<0.05) muscle pH (longissimus thoracis and biceps femoris) at 40 min and 24 h after slaughter in pigs fed the Mg-Aspartate supplemented diet. In contrast, other authors (Kuhn et al., 1981, Apple et al., 1999) did not found significant differences in muscle pH with Mg supplemented pigs. This discrepances (D'Souza et al., 1998, 1999) can follow from different genetic background and not testing animals with DNA based test on occurence of mutation in ryanodine receptor (RYR1) gene because significant differences (P<0.05) can be found between two subgroups in heterozygote pigs (Lahucky et al., 1997). We used biopsy for testing homogenity of heterozygotes (on muscle pH) experimental animals (Lahucky et al., 2000) before Mg supplementation. Tendency on higher muscle pH with Mg-Aspartate supplemented heterozygotes pigs were also found by Schaefer et al. (1993). Apart from, magnesium supplementation has increased (P<0.05) also pH value of normal pigs compared to control group. Similarities in tendency we found also in conductivity values measured 24 h after slaughter but differences were not significant (P>0.05). Dietary magnesium supplementation did not influence surface lightness (P>0.05) as was shown also by others (Schaefer et al., 1993, D'Souza et al., 1999). The LD of pigs fed the diet supplemented with magnesium had lower percentage drip loss compared to pigs fed the control diet.

Significant differences (min. P<0.05) were found between heterozygotes control group and other three groups what is in agreement with Schaefer et al., 1993 and D'Souza et al., 1998, 1999, Hamilton et al., 2002). Reduced percent drip loss would appear to be benefitial in reducing exudative muscle attributes of PSE pork.

Muscle glycogen and lactic acid data are introduced in Table 5. As expected the level of glycogen decreased and level of lactic acid increased in LD when we have compared the results 30 min and 24 h after slaughter. Pigs fed the Mg supplemented diet had higher muscle glycogen and lower muscle lactic acid at 30 min and 24 h post slaughter compared with control pigs. Significant differences (P<0.05) were found between heterozygotes control and MgO normal pigs only. D'Souza et al. (1999) found significantly higher (P<0.05) muscle glycogen and significantly lower muscle lactic acid concentrations in the LD at 5 min, but not at 40 min or 24 h (P>0.05). However, Hamilton et al. (2002) were not able to find statistically significant interactions between magnesium treatment and glycolytic potential (2 {glycogen} + {glucose-6-phosphate} + {glucose}) + lactate) in muscle samples taken ante mortem by biopsy instrument (Biotech PPB-U, Slovakia). Also in cattle (Mojto et al., 1996) was not shown significant influence glycogen level by oral magnesium-aspartate supplementation on stressed animals (mixing unfamiliar animals before slaughter) in muscle samples taken ante mortem and post mortem. The variation in the pig´s response to an acute stressor as negative handling could influence differences in muscle glycogen concentration in some experiments (D'Souza et al. 1999). It was introduced that the action of magnesium is not only via a reduction in plasma catecholamine concentrations, therefore changes in plasma catecholamine concentrations might be an inappropriate method for measuring the effect of magnesium in reducing the effects of stress. It is known that magnesium antagonises calcium within the muscle cell and studies on inhibitory effect of myoplasmic Mg2+ on Ca2+ release from the sarcoplasmic reticulum (Owen et al., 1997) are reliable.

CONCLUSION

Data reported would suggest that magnesium oxide (relatively not expensive and more readily available) may have some prophylactic properties for improving meat quality and decreasing the incidence of inferior (PSE, RSE) meat quality, particularly with regard to drip loss. Further research is needed to clearly establish the impact of supplementary magnesium on some calcium homeostase and energetic metabolism trials in skeletal muscle.

REFERENCES

APPLE, J. K. - DAVIS, J. R. - RAKES, L. K. - MAXWELL, CH. V. - STIVARIUS, M. R. - POHLMAN, F. W. 2001. Effects of dietary magnesium and duration of refrigerated storage on the quality of vacuum-packaged, boneless pork loins. In: *Meat Sci*., vol. 57, no. 1, p. 43-53.

APPLE, J. K. - MAXWELL, CH. - RODAS, B. - DAVIS, J. - RAKES, L. 1999. Influence of Magnesium-Mica on Performance and Carcass Quality Traits of Growing-Finishing Swine. AAES Research Series 470, 23-28.

DREILING, C. E. - BROWN, D. E. - CASALE, L. - KELLY, L. 1987. Muscle glycogen: comparison of jodine binding and enzyme digestion assays and application to meat samples. In: *Meat sci*., vol. 20, p. 167-177.

D´SOUZA, D. N. - WARNER, R. D. - LEURY, B. J. - DUNSHEA, F. R. 1998. The Effect of Dietary Magnesium Aspartate Supplementation on Pork Quality. In: *J. Anim. Sci.*, vol. 76, p. 104-109.

D´SOUZA, D. N. - WARNER, R. D. - DUNSHEA, F. R. - LEURY, B. J. 1999. Comparison of different dietary magnesium supplements on pork quality. In: *Meat Sci.*, vol. 51, p. 221-225.

FUJII, J. - OTSU, K. - ZORZATO, F. - DE LEON S. - KHANNA, V. K. - WEILER, J. - O´BRIEN, P.J.- MCLENNAN, D. H. 1991. Identification of a mutation in porcine ryanodine receptor associated with malignant hyperthermia. In: *Science* (Washington DC), vol. 253, p. 448-451.

HAMILTON, D. N. - ELLIS, M. - HEMANN, M. D. - MCKEITH, F. K. - MILLER, K. D. - PURSER, K. W. 2002. The impact of longissimus glycolytic potential and short-term feeding of magnesium sulfate heptahydrate prior to slaughter on carcass characteristics and pork quality. In: *J. Anim. Sci.*, vol. 80, no. 1, p. 1586-1592.

HONIKEL, K. O. 1998. Reference methods for the assessment of physical characteristics of meat. In: *Meat Sci.*, vol. 49, no. 4, p. 447-457.

CHEAH, K. S. - CHEAH, A. M. - JUST, A. 1998. Identification and Characterisation of Pigs Prone to Producing „RSE" (Redish-Pink, Soft and Exudative) Meat in Normal Pigs. In: *Meat Sci.*, vol. 48, p. 249-255.

KAEMMERER, K. - KIETZMANN, M. - KREIZNER, M. 1984. Untersuchungen mit Magnesium. 2. Mitteilung: Die Wirkung von Magnesium chlorid und Magnesium-aspartat-Hydrochlorid auf Stressreaktionen. In: *Zbl. Vet. Med*., vol. 31, p. 321-333.

KIETZMANN, M. - JABLONSKI, M. 1985. Zur Stressabschirmung mit Mg-aspartat-Hydrochlorid auf Stressreaktion. In: *Zbl. Vet. Med.*, vol. 31, p. 321-333.

KUHN, G. - NOWAK, A. - OTTO, E. - ALBRECHT, V. - GASSMANN, B. - SANDNER, E. - PRZYBILSKI, H. - ZAHN, L. 1981. Untersuchngen zur Beeiflussung der Fleischbeschaffenheit mit Hilfe spezieller Behandlungsverfahren beim Schwein. 1. Mitteillung: Einfluss von Stress und praventiver Magnesium zufutterung auf ausgewahlte Parameter des Schlachtkorperwertes und des Blutserums. In: *Arch. Tierz*., Berlin, vol. 24, p. 217-225.

LAHUČKÝ, R. - MADAJOVÁ, V. - MHARAPARA, O. - MARÁK, J. - KANIANSKY, D. - POLTÁRSKY, J. - KOVÁČ, L. 1995. A comparison of some metabolites in

skeletal muscle of different halothane sensitivity with meat quality traits of pigs using a capillary isotachophoresis technique. In: *Meat Sci.*, vol. 39, p. 403-414.

LAHUČKÝ, R. - CHRISITIAN, L. L. - STADLER, K. J. - KOVÁČ, L. - BAUEROVÁ, M. 1997. Meat Quality Assessed Ante- and Post Mortem by Different Ryanodine Receptor gene Status of Pigs. In: *Meat Sci.*, vol. 47, p. 277-285.

LAHUČKÝ, R. - KRŠKA, P. - KÜCHENMEISTER, U. - NÜRNBERG, K. - LIPTAJ, T. - NÜRNBERG, G. - BAHELKA, I. - DEMO, P. - KÜHN, G. - ENDER, K. 2000. Effect of Vitamin E on changes in Phosphorus Compounds assessed by 31P NMR Spectroscopy and ATPase from postmortem Muscle samples and Meat quality of Pigs. Arch. Tierz., Dummerstorf 43, 487-497.

LUDVIGSEN, J. B. 1985. Intermediary magnesium- and calcium metabolism in stress-susceptible pigs. EAAP publication No. 55 , p. 106-118,

MOJTO, J. - PALANSKÁ, O. - BEŇUŠKA, N. - LAHUČKÝ, R. - ZAUJEC, K. 1996. Overenie magnézium-aspartát-hydrochloridu pri zlepšovaní fyzikálno-technologických vlastností hovädzieho mäsa. In: *Živ. Výroba*, vol. 41, no. 9, p. 397-400.

OWEN, V. J. - TASKE, N. L. - LAMB, G. D. 1997. Reduced Mg2+ inhibition of Ca2+ release in muscle fibers of pigs susceptible to malignant hyperthermia. In: *Am. J. Physiol.*, 272 p., C203-C211.

SCHAEFER, A. L. - MURRAY, A. C. - TONG, A. K. W. - JONES, S. D. M. - SATHER, A. P. 1993. The effect of ante mortem electrolyte therapy on animal physiology and meat quality in pigs segregating at the halothane gene. In: *Can. J. Anim. Sci.*, vol. 73, p. 231-239.

WARRIS, P. D. 1993. Ante-mortem factors which influence carcass shrinkage and meat quality. Proc. 39th Int. Congr. Meat Sci. Technol., Calgary, Canada, p. 51.

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