KRMIVA

THE EFFECT OF HIGH DOSES OF VITAMINS C, E, AND BETA-CAROTENE IN PIGS FEED ON CARCASS AND MEAT QUALITY

DJELOVANJE VISOKIH DOZA VITAMINA C, E I BETA KAROTINA U HRANI SVINJA NA KAKVOĆU POLOVICA I MESA

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SUMMARY

The experiment with 64 crossbred pigs [♀ (♀Polish Landrace × ♂Polish Large White) × ♂Pietrain] was carried out to determine the effect of natural antioxidants (vitamins E, C and beta-carotene) on productivity, meat quality and some biochemical parameters of blood.

Pigs were fattened from approx. 60 to approx. 112 kg of body weight. All pigs were fed the same diet (PT2), which was supplemented with different vitamins (250 mg/kg feed): vitamin C (group II), vitamin E (group III) and beta-carotene (group IV). Group I (control) received no supplements.

The use of high doses of vitamins C, E and beta-carotene in pig diets had a positive effect on daily gains and feed conversion per kg weight gain. Vitamin C was the least efficient, while vitamin E had the greatest effect on meat quality. Vitamin E supplement improved the oxidative stability of meat to a greater extent than did vitamin C. Beta-carotene proved inefficient, especially in the meat stored for 6 months.

The vitamins used reduced cholesterol in loin and improved the water holding capacity of meat.

Key words: pig nutrition, vitamin C, vitamin E, beta-carotene, meat quality

INTRODUCTION

Most of the available studies consider vitamins C, E and beta-carotene as antioxidants without accounting for their effect on pig performance. Hoving-Bolink et al. (1998) reported that vitamin E had no effect on weight gains or feed conversion, although a certain improvement in weight gains of fattening pigs receiving 200 mg/kg vitamin E was observed by Urbańczyk et al. (1999). This supplement also improved carcass quality. In model studies with rats, Sanchez and Lutz (1998) found that with the use of different dietary fats, the

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supplement of the antioxidants vitamin E and beta-carotene slightly reduced feed conversion. The findings of Mahan et al. (1994) indicated that vitamin C supplemented to feed improved weight gains of piglets only to 2 weeks after weaning and had no effect on fattening performance of older animals. Most recent papers dispute even the positive effect of ascorbic acid on young animals (Mavromichalis and Baker, 1999).

The oxidation processes that take place in animal bodies and provide energy essential for life at the same time lead to some unfavourable changes. These processes result in the generation of highly active free radicals and fatty acid peroxides. Vitamins are a group of highly effective antioxidants. The most important physiological antioxidants that protect the interior of cell membranes are vitamin E and beta-carotene, while the antioxidant vitamin C protects the water environment of cells.

The antioxidative properties of vitamins can also influence the quality of meat, especially its colour, water holding capacity and oxidative stability (Asghar et al., 1991; Monahan et al., 1992). Some studies indicate that vitamin E can also positively affect the dietetic value of meat by inhibiting cholesterol oxidation processes (Flader et al., 2003). Lin et al. (1994) obtained better colour stability of beef when they injected animals with sodium ascorbate prior to slaughter.

The aim of the present study was to determine the efficiency of high doses of vitamin E, C and beta-carotene in feed on fattening performance, biochemical parameters of blood, and carcass and meat quality.

MATERIAL AND METHODS

A total of 64 [♀ (♀Polish Landrace × ♂Polish Large White) × ♂Pietrain] fattening pigs were divided into four groups of 16 animals, each having 8 gilts and 8 barrows. Throughout the experiment, all the animals received the same PT2 standard mixture containing 13 MJ metabolizable energy, 15.2% crude protein, 0.7% lysine, and 0.5% methionine and cystine. The diet, which contained mainly barley, wheat and soybean meal, was supplemented with 4% rapeseed oil. The experimental groups varied according to the type of vitamins supplemented:

Group I – control, without supplemental vitamins

Group II – vitamin C, 250 mg/kg feed

Group III – vitamin E, 250 mg/kg feed

Group IV – beta-carotene, 250 mg/kg feed

The animals were kept in individual pens equipped with nipple drinkers. The experimental fattening was conducted from 60 to approximately 112 kg of body weight. In the experiment, animals were fed individually with restricted diets of 2.8 kg at 60 kg of body weight, 3.0 kg at approx. 70 kg of body weight, and 3.2 kg in the finishing period (above 80 kg of body weight). At about 112 kg of body weight, pigs were slaughtered and their right half-carcasses dissected according to Pig Testing Station methodology (Stan hodowli...1995).

Fresh meat was analysed for L*a*b* colour using a Minolta CR-310 colourimeter. Lightness (L*), redness (a*) and yellowness (b*) were measured. Water holding capacity was determined in fresh minced meat using the method of Grau and Hamm (1953). Meat cholesterol was determined colourimetrically using the method of Rhee et al. (1982). Fat oxidation TBA-RS (mg malonaldehyde per kg meat) was determined photometrically at 2 weeks and 6 months of storing frozen meat samples, using the modified method of Salih as described by Pikul (1989).

The basic analysis of diets and samples of the *longissimus* muscle, taken behind the last rib, was made using standard methods (AOAC, 1990).

During slaughter, blood samples were taken and serum was centrifuged to determine the levels of total cholesterol (TC), high-density lipoprotein (HDL) cholesterol and triacylglycerols (TAG) using enzymatic methods and Cormay diagnostic kits. Low-density lipoprotein (LDL) cholesterol was calculated from the Friedewald formula (after Szostak and Cybulska, 1985).

$$LDL = TC - HDL - triacylglycerols / 5$$

The level of the other biochemical components of blood (total protein, total lipids) was also determined enzymatically using Beckman DU640 spectrophotometer and Cormay diagnostic kits.

The results were analysed statistically using two-way variance analysis and Duncan's multiple range test (Statistica 5).

RESULTS

The results indicate that the use of vitamin E and beta-carotene supplements resulted in a statistically significant increase in daily gains of pigs (Table 1). The difference in relation to the control pigs was 59 g (7.7%) for animals receiving vitamin E, 55 g (7.1%) for animals receiving beta-carotene, and 42 g (5.5%) for animals receiving vitamin C. The experimental animals also used 3.4-7.2% less feed per kg weight gain than the control animals. No statistically significant differences were found in daily gains or feed conversion per kg weight gain between gilts and barrows.

The supplements had a positive effect on the slaughter yield of pigs, with statistically significant differences. For carcasses of animals receiving vitamin C, they were highly significant. The vitamin supplement had no clear effect on meat deposition in carcass, although loin eye area of animals receiving vitamin E was 4% greater than that of the control animals. The increased proportion of vitamins, especially beta-carotene, had a highly significant effect on reducing backfat thickness. Supplemental vitamins decreased the weight of kidney, significantly with vitamin E. At the same time, liver weight increased significantly in animals receiving vitamin C. Carcasses of gilts were characterized by better meatiness and lower fatness compared to barrows.

Table 1. Fattening results (60 – 112 kg BW) and carcass quality parameters
Tablica 1. Rezultati tova (60-112 kg tj. težine) i pokazatelji kakvoće polovica

Item - Stavka	Control (without vitamin additives) Kontrola (bez dodatka vitamina)	Vitamin C 250 mg /kg	Vitamin E 250 mg / kg	Beta-carotene β-karotin 250 mg / kg	Sex - Spol		SEM	Int.
					gilts nazimice	barrows kastrati		
Average daily weight gains (g) Prosječni dnevni prirast težine (g)	770 a	812 ab	829 b	825 b	815	803	9,65	NS
Feed conversion per 1kg BWG (kg) Konverzija hrane po 1 kg prirasta tjelesne težine (kg)	3,87 b	3,74 ab	3,59 a	3,73 ab	3,74	3,73	0,04	NS
Cold dressing yield (%) Prirast hladnog randmana (%)	77,5 Aa	78,4 AB b	78,17 AB b	78,0 AB b	78,0	78,1	0,10	**
Meat content in proper ham (%) Sadržaj mesa u butu (%)	73,7	74,2	75,4	75,5	75,3	74,1	0,43	NS
Loin eye area (cm^2) - Površina musculus longissimusa dorsi (cm^2)	52,68	53,07	54,78	52,63	54,23	52,35A	0,79	NS
Meat content in primal cuts (kg) Sadržaj mesa u prvim odrescima (kg)	25,11	25,09	25,98	24,76	25,68	24,79	0,26	NS
Meatness of carcass (%) Mesnatost polovica (%)	57,75	57,42	58,70	58,79	59,59B	56,73 A	0,48	NS
Backfat thickness of 5 meas. (cm) Debljina leđne slanine u 5 mjerenja (cm)	2,58 Bb	2,53 ABb	2,50 ABb	2,23 Aa	2,34 A	2,58 B	0,04	NS
Backfat thickness in point C (cm) Debljina leđne slanine na točki C (cm)	1,20	1,19	1,14	1,07	1,04 A	1,25 B	0,03	NS
Liver weight - Težina jetre (kg)	1,63	1,73	1,62	1,64	1,69	1,61	0,03	**
Kidney weight - Težina bubrega (g)	162 b	147 ab	145 a	149 ab	155	146	2,66	NS

a, b - $P \leq 0,05$

A, B - $P \leq 0,01$

NS - $P > 0,05$

** $P \leq 0,01$

Determinations in blood serum did not show consistent changes in selected parameters (Table 2). Blood of experimental pigs contained more total lipids than that of control animals. Supplemental vitamin E increased the amount of HDL cholesterol and these fatteners also showed the most beneficial ratio of HDL cholesterol to total cholesterol. It was also found that this ratio was more favourable in the blood of gilts compared to barrows ($p \leq 0.05$).

The results of meat analysis given in Table 3 point to varying effects of vitamins on the chemical composition of meat. Vitamin C and beta-carotene supplements caused a highly significant reduction of protein in the *longissimus* muscle, while supplemental vitamin E increased the dry matter and fat content of this muscle. The supplements did not exert a significant effect on meat acidity, both at 45 min postmortem (6.17-6.36) and after 24 h carcass cooling (5.49-5.57). Colour lightness (L*) and yellowness (b*) did not differ within groups either. The meat of experimental animals was characterized by greater redness (a*).

The presence of the analysed vitamins had a positive effect on quality traits such as water holding capacity, cholesterol level and oxidative stability of meat postmortem. After 6-month storage in a frozen state, only vitamin E turned out to be an effective antioxidant ($p \leq 0.01$).

DISCUSSION

The use of high doses of vitamins C, E and beta-carotene in pig diets had a positive effect on daily gains and feed conversion per kg weight gain. Vitamin C was the least effective. Mahan (1992/93) and Mahan et al. (1994) observed a positive effect of vitamin C on weight gains and feed conversion but only in the first period of pig fattening. A review of literature by Mavromichalis and Baker (1999) showed that only in 1 out of 13 experiments, weight gains of piglets were found to improve together with a 13% increase in feed intake.

The vitamin E supplement proved the most beneficial in terms of both average daily gains and feed intake. When using vitamin E supplements of 50-200 mg/kg feed, Soler-Velasquez et al. (1998) did not improve weight gains. It appears that the efficiency of increased doses of vitamin E in pig feed depends on the amount of dose, age of animal and type of feed, as indicated by the findings of Asghar et al. (1991), Grela (1992) and Corino et al (1999).

Table 2. Biochemical blood serum indices
Tablica 2. Biokemijski indeksi krvnog seruma

Item - Stavka	Control (without vitamin additives) Kontrola (bez dodatka vitamina)	Vitamin C 250 mg /kg	Vitamin E 250 mg / kg	Beta-carotene β-karotin 250 mg / kg	Sex - Spol		SEM	Int.
					gilts nazimice	barrows kastrati		
Protein - Bjelančevina (g/dl)	7,74	7,71	7,93	7,47	7,76	7,67	0,08	NS
Lipids - Lipidi (mg/dl)	226 A	308 B	261 AB	266 AB	295 B	235 A	10,02	**
Triglicerides - Trigliceridi (mmol/l)	0,50	0,62	0,50	0,48	0,46 a	0,59 b	0,03	NS
Total cholesterol (mmol/l) Ukupni kolesterol (mmol/l)	2,61	2,77	2,65	2,63	2,52 A	2,81 B	0,05	NS
Cholesterol HDL (mmol/l) Kolesterol HDL (mmol/l)	1,00 ab	0,99 a	1,14b	1,06 ab	1,03	1,07	0,02	NS
Cholesterol LDL (mmol/l) Kolesterol LDL (mmol/l)	1,37	1,48	1,24	1,34	1,27 a	1,44b	0,04	NS
HDL / TC	0,388 Aab	0,359 Aa	0,436 Bc	0,407 ABbc	0,411 b	0,384 a	0,01	NS

a, b, c - $P \leq 0,05$
A, B - $P \leq 0,01$
NS - $P > 0,05$
** $P \leq 0,01$

Table 3. Results of meat quality estimation
Tablica 3. Rezultati procjene kakvoće mesa

Item - Stavka	Control (without vitamin additives) Kontrola (bez dodatka vitamina)	Vitamin C 250 mg /kg	Vitamin E 250 mg / kg	Beta-carotene β-karotin 250 mg / kg	Sex - Spol		SEM	Int.
					gilts nazimice	barrows kastrati		
Chemical analysis (%): Kemijska analiza (%):								
- dry matter - suha tvar	25,83 ABb	24,77 Aa	26,69 Bc	25,63 ABb	25,96	25,50	0,17	*
- crude protein - sirova bjelančevina	23,80 B	22,63 A	23,86 B	22,26 A	23,30	22,98	0,15	NS
- crude fat - sirova masnoća	1,22 ab	1,08 a	1,51 b	1,33 ab	1,23	1,34	0,06	NS
pH 45 min. after slaughter pH 45 min nakon klanja	6,24	6,17	6,29	6,36	6,25	6,28	0,03	NS
pH after 24 h. freezing pH poslije 24 sata smrzavanja	5,57	5,52	5,53	5,49	5,46 a	5,60 b	0,03	NS
Meat colour in (L*a*b) system : Boja mesa u (L*a*b) sustavu								
- lightness - svjetlost (L)	54,13	54,17	53,02	52,51	54,23	52,68	0,43	NS
- saturation in red (a) - zasićenje u crvenom (a)	13,63 Aa	15,70 Cc	14,58 ABb	15,29 BC bc	14,79	14,81	0,17	NS
- saturation in yellow (b) - zasićenje u žutom (b)	5,35	5,64	5,10	5,25	5,61 b	5,06 a	0,14	*
Water holding capacity (%) Sposobnost zadržavanja vode (%)	28,10 bB	25,48 a AB	23,94 aA	26,19 abAB	25,76	26,10	0,45	NS
TBA-RS after 2 weeks TBA-RS nakon 2 tjedna	0,586 Bc	0,381 ABa	0,324 Aa	0,427 Bb	0,466 b	0,393 a	0,02	NS
TBA-RS after 6 months TBA-RS nakon 6 mjeseci	0,785 B	0,697 B	0,417 A	0,812 B	0,747 B	0,609 A	0,03	NS
Total cholesterol (mg/100g meat) Ukupni kolesterol (mg/100 g mesa)	83,08 Bb	65,46 Aa	66,70 Aa	74,12ABa	72,21	71,5	1,75	NS

a, b, c - P≤0,05
A, B - P≤0,01
NS - P> 0,05
** P≤0,01

The positive effect of beta-carotene has not been confirmed in literature except by Tai et al. (1992), who found slightly higher gains in rats supplemented with beta-carotene.

Besides the effect of supplemental vitamins on weight gains of pigs, no clear improvements in carcass quality were observed. Mean backfat thickness decreased slightly, especially in pigs receiving beta-carotene, while loin eye area increased in animals fed the diet supplemented with vitamin E. It is also worth noting the slaughter yield, which was higher in experimental fatteners. With vitamin E improved slaughter yield was observed by Corino et al. (1999).

The results of biochemical determinations of blood were not clearly dependent on the vitamins added, as also observed by Urbańczyk et al. (1999), but the HDL to total cholesterol ratio was the most beneficial in animals receiving vitamin E. Cholesterol content of meat proved significantly lower in vitamin supplemented animals compared to control animals. Grela (2000) also obtained a slight decrease in cholesterol in the meat of pigs receiving 500 mg/kg vitamin E in their diet. Zanardi

et al. (2000) found cholesterol to decrease in cured pork products from pigs receiving 100 or 200 mg vitamin E/kg feed. A marked decrease in meat cholesterol was also found in fatteners fed a diet containing 250 mg vitamin C.

The present results indicate that the vitamins added to feed did not have a clear effect on meat acidity and colour, although redness was more favourable. This can be related to improved oxidative stability of meat, as reflected in TBA-RS value. Monahan et al. (1992) and Kirchheim et al. (2001) found that vitamin E added to feed stabilizes meat colour. The oxidative stability of meat, which was the lowest in animals receiving vitamin E, suggests that it is the most effective antioxidant, especially during long storage. It should also be noted that the supplemented vitamins increased the water holding capacity of meat.

Buckley et al. (1995) hold that vitamin E increases the protection of cell membranes, thus reducing the drip loss of meat.

CONCLUSIONS

1. The present results allow concluding that the dietary supplement of vitamin E and beta-carotene improved pig performance.
2. Vitamin E supplement improved the oxidative stability of meat to a greater extent than did vitamin C, while beta-carotene proved inefficient when the meat was stored for 6 months.
3. The vitamins used reduced cholesterol in loin meat.
4. The presence of the high doses of vitamins C, E and beta-carotene in pig diets improved the water holding capacity of meat.

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SAŽETAK

Pokus je izveden na 64 križane svinje [♀ (♀Poljski landras x ♂Poljski veliki bijeli) x ♂Pietrain] da se ustanovi djelovanje prirodnih antioksidanata (vitamina E, C i beta karotina) na proizvodnost, kakvoću mesa i neke biokemijske pokazatelje u krvi.

Svinje su tovljene od otprilike 60 kg tjelesne težine do oko 112 kg. Sve su svinje hranjene istim obrocima (PT2) kojima su dodavani razni vitamini (250 mg/kg hrane): vitamin C (skupina II) i vitamin E (skupina III) i beta karotin (skupina IV). Skupina I (kontrolna) nije dobivala dodatke.

Upotreba visokih doza vitamina C, E i beta karotina u obrocima svinja pozitivno je djelovala na dnevni prirast i konverziju hrane po kg prirasta težine. Vitamin C bio je najmanje djelotvoran, dok je vitamin E imao najveći učinak na kakvoću mesa. Dodatak vitamina E poboljšao je oksidacijsku stabilnost mesa u većoj mjeri od vitamina C. Beta karotin se pokazao nedjelotvornim, osobito u mesu čuvanom 6 mjeseci.

Upotrijebljeni vitamini smanjili su kolesterol u slabinama i poboljšali sposobnost zadržavanja vode u mesu.

Ključne riječi: hranidba svinja, vitamin C, vitamin E, beta karotin, kakvoća mesa