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Effect of Dietary Supplement of Herbal Extract from Hop (*Humulus lupulus*) on Pig Performance and Meat Quality

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ABSTRACT

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The study deals with the effect of diets supplemented with a hop extract on growing pigs. Two levels of the extract (500 or 1000 mg/kg of diet) were used. Feeds either unsupplemented or supplemented with butylated hydroxytoluene were used as negative and positive controls. Totally 96 pigs weighing ca. 60 kg were allocated to 4 groups. They were fed individually with restricted feed amounts. Water was available *ad libitum.* Body weight gain, apparent digestibility of nutrients, carcass and meat quality were estimated and biochemical indices in the blood were analyzed. The herbal extract decreased digestibility of fat and its higher dose also lowered protein deposition and mean body weight gains. Both doses of the extract lowered liver and kidney weight. The extract also improved meat oxidative and colour stability, decreased its cholesterol content, and positively affected the fatty acids pattern. A higher dose of the extract resulted in a worse smell and taste of meat.

Keywords: hop extract; fattening pigs; carcass quality; oxidative stability

Herbs and herbal extracts have been used in veterinary medicine for a long time (Viegi et al. 2003) with health promoting effects found also in pigs and poultry (Windisch et al. 2008). They have attracted increasing interest as an alternative feeding strategy to replace antibiotic and growth promoters (Hernandez et al. 2004). In the experiment of Hanczakowska et al. (2015) the positive effect of herbal extract, among others from sage and nettle, on meat oxidative stability and the composition of meat lipid fraction was observed but without any improvement in pig performance.

One of the plants used both in human and veterinary medicine is the hop (Zanoli and Zavatti 2008). The health promoting effects of plants depend on the content of active substances. Hop contains bitter acids, polyphenols, and essential oils. It has antidepressant (Zanoli et al. 2005) and sedative effects (Chadwick et al. 2006). It also shows antimicrobial activity (Van Cleemenput et al. 2009; Landete 2012) which makes it a good preservative of meat (Kramer et al. 2015). Perhaps it may also improve nutrients digestibility because Kurosawa et al. (2005) have shown that a hop-dried extract

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administered orally increases gastric juice volume in rats without affecting acidity.

Data on the use of hop or hop extract in animal feeding is scarce. Ruminant feeding including hop in high-grain diets may have the potential to improve feed efficiency, possibly by reducing enteric methane emissions (Narvaez et al. 2010). A positive effect of the hop extract was also found in non-ruminant (chicken) feeding. The growth performance of birds fed this extract was better than of those receiving an antibiotic growth promoter (Bozkurt et al. 2009). In available literature information on the use of hop in pigs fattening remains scarce. Although the hope extract is more expensive than docosahexaenoic acid (DHA) used as control, it is a natural agent and in addition to its antioxidant activity it has various health-related effects.

The aim of the present experiment was to assess the effect of diets supplemented with hop extract on pig performance, nutrient digestibility, and meat quality.

MATERIAL AND METHODS

Animals and diets. All procedures included in the experiment were in accordance with regulations of the Second Local Cracow Ethics Committee for Experiments with Animals in Cracow, Poland.

The experiment was carried out on 96 fatteners of both sexes (12 female and 12 castrated male pigs in one experimental group) originating from Polish Landrace × Polish Large White sows mated with a Duroc × Pietrain boar from 60 to 115 kg of body weight (BW). They were allocated to 4 groups fed the same barley, wheat, soybean meal containing rape seed oil (150 g crude protein, 13.2 MJ metabolizable energy, and 8 g lysine per 1 kg diet). Group I (negative control) received a diet with no supplement; Group II (positive control) received the synthetic antioxidant butylated hydroxytoluene (BHT) (150 mg per kg feed); and Groups III and IV received 500 and 1000 mg of hop (*Humulus lupulus*) dried water extract per kg of feed, respectively. The extracts were supplied by Phytopharm Ltd., Nowe Miasto and Wartą, Poland.

At the beginning of the experiment each pig weighed approximately 60 ± 0.5 kg. The animals were kept in individual straw-bedded pens and were fed individually twice a day with restricted feed amounts, according to their BW: from 2.8 kg feed mixture/day at 60 kg BW to 3.2 kg/day at 80 kg BW and upwards. The individual BW of all fatteners were recorded every two weeks. During the trial the animals had free access to water. At the end of the experiment all the animals were slaughtered at about 115 ± 2.0 kg BW and the carcasses of 16 animals (8 barrows and 8 gilts) from each group were dissected after a 24-hour chilling.

Apparent digestibility and protein deposition were evaluated in parallel to the fattening experiment, using the same feeds, on 24 fattener barrows weighing around 70 kg, not used in the fattening part of the experiment. The scheme of the digestibility trial was the same as that of the fattening experiment. Each group consisted of 6 fatteners. The animals were kept individually in balance cages and fed with the same feeds as in the fattening experiment (3.0 kg of feed mixture daily). The preliminary period lasted 10 days and the samples collection lasted 5 days. Faeces and urine from each animal were collected daily, weighed and frozen at –20°C. At the end of the collection period, faeces and urine samples from each animal were taken, mixed, and a representative sample was prepared. Chemical composition of the faeces samples and nitrogen content of the urine were analyzed according to AOAC (2005) methods.

Physical parameters. The quality of carcasses was evaluated according to Tyra and Zak (2012). Average backfat thickness calculated from 5 measurements (at the thickest point over the shoulder; on the back above the joint between the last thoracic and the first lumbar vertebrae; at three points over the loin; above the rostral edge (loin I), above the middle (loin II), and above the caudal edge (loin III) of gluteal muscle cross-section) was used as a fatness indicator. Muscling was determined by estimating carcass meat content using the following formula:

$$y = 1.745x_1 + 0.836x_2 + 0.157x_3 - 1.884$$

where:

y = calculated meat content (kg)
x_1 = ham without skin and backfat (kg)
x_2 = loin without backfat + tenderloin (kg)
x_3 = double loin eye width + loin eye height (2A + B) (cm)

The meat content of primal cuts calculated from this formula was expressed as a percentage of chilled carcass weight.

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Samples of the *Longissimus thoracis* (LT) muscle were taken for analysis from the area of the last thoracic vertebrae. Meat acidity was measured 45 min and 24 h after slaughter with a pH meter equipped with a Metron OSH 12-00 electrode. Using the CIE L*a* b* system (L* = lightness, a* = redness, b* = yellowness), the colour of fresh meat and meat after 6 months of storage at –20°C was estimated with a Minolta colorimeter. On this basis, chroma C* and total colour difference ΔE* were calculated according to MacDougall (2002):

$$C^* = (a^{*2} + b^{*2})^{1/2}$$

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The water-holding capacity of the meat was measured according to Grau and Hamm (1953).

Cholesterol and fatty acid content. Cholesterol content was estimated according to Rhee et al. (1982). The fatty acid profile was determined after two weeks of freezing at –20°C, immediately after thawing, using a CP-Wax 58 capillary column (Varian BV, the Netherlands) (25 m, 0.53 mm; df: 1 μ; carrier gas: helium; 6 ml/min), with a column oven temperature programme from 90 to 200°C, using a Varian 3400 gas chromatograph (Varian Inc., USA) equipped with a Varian 8200 CX autosampler (200°C), FID detector (260°C), and Star Chromatography Workstation software. Fatty acids were identified by comparing the retention time of each fatty acid with its respective standard. All analyses were performed in duplicate and mean values are reported.

Oxidative stability evaluation. The samples for thiobarbituric acid reactive substances (TBARS) level determination were frozen at –20°C and then analyzed twice: after 2 weeks and after 6 months of storage, in each case immediately after thawing. Meat samples were prepared according to the method of Salih with modifications (Pikul et al. 1989). Lipid quality indices, i.e. the atherogenic index (AI) and thrombogenicity index (TI), were calculated (Σg/100 g) according to Ulbricht and Southgate (1991):

$$AI = [(4 \times C14{:}0) + C16{:}0]/[\text{n-6 PUFA} + \text{n-3 PUFA} + \text{MUFA}]$$

$$TI = [C12{:}0 + C14{:}0 + C16{:}0 + C18{:}0]/[(0.5 \times \text{MUFA}) + (0.5 \times \text{n-6 PUFA}) + (3 \times \text{n-3 PUFA}) + \text{n-3/n-6 PUFA}]$$

where:
PUFA = polyunsaturated fatty acids
MUFA = monounsaturated fatty acids

The hypocholesterolemic (h) to hypercholesterolemic (H) ratio (h/H) was calculated according to Fernandez et al. (2007):

$$h/H = (C18{:}1 + C18{:}2 + C18{:}3 + C20{:}4 + C20{:}5 + C22{:}6)/(C14{:}0 + C16{:}0)$$

The peroxidisability index (PI) was calculated (g/100 g) according to Arakawa and Sagai (1986):

$$PI = (\%\ \text{monoenoic} \times 0.025) + (\%\ \text{dienoic} \times 1) + (\%\ \text{trienoic} \times 2) + (\%\ \text{tetraenoic} \times 4) + (\%\ \text{pentaenoic} \times 6) + (\%\ \text{hexaenoic} \times 8)$$

The iodine value (IV) of fat was calculated (g/100 g) using the following equation (AOCS 1998):

$$IV = (C_{16:1}) \times 0.95 + (C_{18:1}) \times 0.86 + (C_{18:2}) \times 1.732 + (C_{18:3}) \times 2.616 + (C_{20:1}) \times 0.785 + (C_{22:1}) \times 0.723$$

Sensory analysis. The sensory evaluation of meat after 6 months of storage at –20°C was made using a 5-point scale (1 – the poorest, 5 – the best). Samples were thawed at +4°C, cut into approximately 30 mm thick slices, and boiled in 0.6% NaCl solution to an internal temperature of +80°C. After cooking, the meat was left for 2 min in order to even out the temperature between its layers (Barylko-Pikielna 1975). Then the slices were cut into smaller pieces and presented to the panelists. The evaluation board consisted of 6 trained experts who evaluated the odour, taste, tenderness, and juiciness of the meat.

Statistical analysis. The significance of differences between the groups was calculated with one-way (digestibility) or two-way (remaining results performance, carcass and meat quality indices, cholesterol and fatty acids content, oxidative stability indices) analysis of variance (ANOVA) and Duncan's multiple range test using the software package STATISTICA (Version 10, 2011).

RESULTS

The hop extract given at 500 mg significantly decreased the apparent digestibility of dry matter ($P < 0.05$) and N-free extractives ($P < 0.01$)

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(Table 1). All the supplements also lowered the digestibility of fat ($P < 0.05$). The extract given at 1000 mg and BHT reduced the protein deposition ($P < 0.01$), although protein digestibility did not change. A higher level of extract showed a trend ($P = 0.061$) to reduce feed conversion in comparison to its lower level and control.

The only significant difference in body weight gains (BWG) was found between lower (BWG 876 g) and higher (BWG 809 g) doses of the extract (Table 2). All the supplements significantly improved cold dressing yield but there was no difference between the hop extract and the positive control (BHT group). The extract also significantly ($P < 0.01$) lowered liver weight. Its lower dose also lowered ($P < 0.05$) kidney weight when compared to both the negative and positive control groups. Sex had no effect on animal performance and little effect on carcass quality except for a significantly ($P < 0.01$) lower loin eye area and a trend ($P = 0.074$) to lower kidney weight in barrows. The barrows also had less meat in primal cuts ($P = 0.071$) than the gilts.

All the supplements significantly ($P < 0.01$) improved meat oxidative stability after 6 months of freezing (Table 3). The higher dose of hop extract improved it earlier, after two weeks of freezing ($P < 0.01$). The supplements also had a positive effect on the cholesterol content of the meat, which was lowered from 64.0 mg/100 g in the control to 51.4–53.4 mg/100 g in the experimental groups. There was no significant difference in meat water holding capacity.

There was no difference in meat colour immediately after slaughter (Table 3) but it was less saturated in yellow ($P < 0.01$) after 6 months of storage in all the groups receiving the supplements. Higher colour stability (lower ΔE) was found in the meat of pigs fed with the supplements than in the control ones.

The taste of the meat from pigs receiving the higher dose of extract was estimated as significantly worse than that from the remaining groups.

The supplements also had a positive effect on the fatty acids profile of the meat (Table 4). All supplements significantly reduced ($P < 0.05$) the content of saturated fatty acids and both doses of extract raised ($P < 0.01$) the content of unsaturated acids. At the same time, the content of PUFA n-3 acids was, in animals from the experimental groups, more than twice as high as in the negative control group. Due to these changes the atherogenic index and thrombogenicity indexes in animals receiving the extract were significantly lower ($P < 0.05$) than those in both control groups. The peroxydisability index was higher ($P < 0.05$) in all the supplemented groups, and the iodine value was higher ($P < 0.01$) in animals receiving the hop extract than that in the negative control group. The gilts' meat had a better fatty acid profile than that of the barrows.

DISCUSSION

While positive results were obtained when hop was used in ruminant (Narvaez et al. 2010) and broiler diets (Cornelison et al. 2006), in the experiment of Williams et al. (2005) on newly weaned piglets no improvement in growth performance was found. Also, in the present experiment carried out on growing pigs, no significant difference between the control and experimental groups was found, although animals fed a lower dose of hop grew

Table 1. Coefficients (%) of apparent digestibility of nutrients in feed mixtures

Item	Experimental groups (n = 6 per each group)				P-value	SEM
	control	butylated hydroxytoluene	hop extract			
			500 mg/kg	1000 mg/kg		
Dry matter	83.8^{b}	83.2^{b}	81.2^{a}	82.7^{b}	0.03	0.33
Crude protein	80.2	79.0	78.5	78.5	0.40	0.39
Ether extract	74.1^{b}	69.7^{a}	67.8^{a}	69.6^{a}	0.04	0.84
Crude fibre	42.5	45.5	42.5	47.7	0.13	0.92
N-free extractives	87.6^{B}	87.5^{B}	85.3^{A}	86.1^{B}	0.01	0.30
Nitrogen retention (%)	49.1	46.7	48.1	48.8	0.55	0.61
Protein deposition (g/day)	188.8^{B}	166.0^{A}	186.8^{B}	166.9^{A}	0.003	3.19

means in the same row with different superscripts significantly differ at $^{a,b}(P \leq 0.05)$ and $^{A,B}(P \leq 0.01)$

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significantly better ($P < 0.05$) than those receiving a higher amount of the extract. This result is hard to explain on the basis of the other results obtained: the digestibility of dry matter and fat was higher in the latter group and there was no difference in feed conversion. In the experiment of Fiesel et al. (2014) on piglets, a supplement of spent hop significantly improved the gain/feed ratio, although protein and organic matter digestibility was decreased. There was no difference in daily BWG. According to the authors such results could be the result of changes in intestinal microflora, but such an analysis was not performed in our experiment.

Lower liver weight found in this experiment was not in accordance with the results of Bozkurt et al. (2009) who found a higher liver weight in broilers fed mixtures supplemented with hop extract. According to Debersac et al. (2001) plant extracts may enhance the hepatic metabolism and affect liver weight. Nagasako-Akazome et al. (2007), in their toxicological evaluation of hop extract on rats, found no change in liver and kidney weight during the 90-day experiment. In another experiment (unpublished) we found only a numerical decrease in pig liver weights when extracts from lemon balm and cone flower were used but kidney weight was, as in the present experiment, significantly lower. Polyphenols are the main active substances in hop (Nagasako-Akazome et al. 2007) and these compounds can decrease kidney weight (Yokozawa et al. 2005). Unfortunately their content was not analyzed in this experiment.

Plants and plant extracts are a rich source of phenolics that exhibit a wide range of physiological properties (Balasundram et al. 2006), one of which is a potent antioxidant activity. It is also true in the case of hop extract (Gerhauser et al. 2002) the antioxidative activity of which was also found in this experiment. This activity maintains meat colour after 6 months of storage, probably by preventing the conversion of myoglobin to metmyoglobin (Faustman and Cassens 1990). Another positive effect of the hop extract was a lowering of the cholesterol content in the meat. We also found such a lowering in the case of other plant extracts (Hanczakowska et al. 2007a) but we did not examine the mechanism of this hypocholesterolemic activity. The hypocholesterolemic activity of plant extract may be due to a decrease in cholesterol absorption and an increase in fecal cholesterol and bile acids excretion (Wang et al. 2012).

Table 2. Fattening performance and carcass quality indices

	Experimental group (G)				Sex (S)		SEM	*P*-value		
	control	butylated hydroxytoluene	hop extract 500 mg/kg	hop extract 1000 mg/kg	gilts	barrows		G	S	I*
Average daily weight gains (g)	857^{ab}	840^{ab}	876^{b}	809^{a}	843	848	8.56	0.04	0.73	0.37
Feed conversion (kg/kg)	3.60	3.67	3.53	3.82	3.67	3.64	0.04	0.06	0.74	0.32
Body weight before slaughter (kg)	116.4	115.9	116.2	116.0	116.5	115.7	0.40	0.97	0.38	0.40
Cold dressing yield (%)	78.4^{Aa}	79.0^{ABb}	79.1^{Bb}	79.4^{Bb}	79.0	78.9	0.10	0.004	0.62	0.10
Lean content in the ham proper (%)	77.5	76.3	76.4	76.2	77.0	76.2	0.40	0.61	0.30	0.40
Loin eye area (cm^2)	58.7	59.4	61.0	59.0	61.3^{B}	57.7^{A}	0.65	0.52	0.004	0.65
Meat in primal cuts (kg)	24.0	23.9	24.0	23.8	24.4	23.5	0.24	0.99	0.07	0.37
Meat content in carcass (%)	54.1	54.0	53.7	53.3	54.6	53.0	0.49	0.93	0.10	0.28
Backfat thickness (5 measurements, cm)	2.31	2.50	2.55	2.46	2.44	2.46	0.04	0.23	0.81	0.06
Backfat thickness in point C (cm)	1.00	1.04	1.08	1.00	0.98	1.08	0.03	0.75	0.12	0.09
Liver weight (kg)	1.93^{Bc}	1.78^{ABb}	1.72^{Aab}	1.70^{Aa}	1.82	1.74	0.03	0.006	0.14	0.53
Kidney weight (kg)	166^{b}	164^{b}	150^{a}	160^{ab}	166	154	2.19	0.03	0.07	0.51

I* = interaction
means in the same row with different superscripts significantly differ at $^{a-c}(P \leq 0.05)$ and $^{A,B}(P \leq 0.01)$

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Table 3. Meat quality traits of *Longissimus thoracis* muscle

	Experimental group (G) (n = 16 per each group)				Sex (S) (n = 32 per each group)		SEM	P-value		
	control	butylated hydroxytoluene	hop extract		gilts	barrows		G	S	I*
			500 mg/kg	1000 mg/kg						
pH 45 min after slaughter	6.21	6.33	6.29	6.32	6.30	6.27	0.33	0.17	0.41	0.22
pH after 24 h cooling	5.52^{a}	5.62^{b}	5.57^{ab}	5.64^{b}	5.61	5.57	0.02	0.04	0.23	0.21
Water holding capacity (%)	22.43	21.26	21.50	20.21	21.05	21.45	0.49	0.14	0.37	0.38
TBA after 2 weeks (mg/kg)	0.450^{b}	0.469^{b}	0.440^{ab}	0.396^{a}	0.434	0.443	0.009	0.04	0.57	0.82
TBA after 6 months (mg/kg)	0.743^{B}	0.560^{A}	0.499^{A}	0.595^{A}	0.587	0.576	0.01	< 0.001	0.67	0.33
Total cholesterol (mg/100 g)	64.0^{B}	53.4^{A}	53.1^{A}	51.5^{A}	55.7	55.3	0.98	< 0.001	0.96	0.97
Meat colour after slaughter										
Lightness (L*)	52.08	51.54	51.54	50.89	51.24	51.78	0.37	0.73	0.48	0.27
Redness (a*)	15.41	15.35	15.55	15.60	15.59	15.37	0.09	0.77	0.25	0.69
Yellowness (b*)	3.69	3.57	3.72	3.35	3.52	3.64	0.11	0.64	0.60	035
Chroma C*	15.86	15.77	16.03	15.97	16.00	15.82	0.10	0.83	0.40	0.88
Meat colour after 6 months of storage (–20°C)										
Lightness (L*)	50.26	49.43	49.14	48.67	49.06	49.69	0.36	0.46	0.39	0.15
Redness (a*)	14.15	14.66	14.92	15.05	14.66	14.73	0.12	0.06	0.79	0.83
Yellowness (b*)	7.30^{B}	5.94^{A}	6.03^{A}	5.87^{A}	6.26	6.31	0.14	< 0.001	0.82	0.09
Chroma C*	15.94	15.87	16.15	16.09	15.99	16.04	0.10	0.75	0.81	0.99
ΔE	4.87^{B}	3.52^{A}	3.75^{A}	3.51^{A}	3.92	3.90	0.11	< 0.001	0.89	0.58
Meat sensory evaluation										
Odour	4.68^{b}	4.62^{ab}	4.73^{b}	4.43^{a}	4.73^{B}	4.50^{A}	0.04	0.03	0.01	0.50
Taste	4.82^{Bb}	4.60^{ABb}	4.68^{Bb}	4.36^{Aa}	4.72^{B}	4.50^{A}	0.04	0.006	0.03	0.90
Tenderness	4.78	4.40	4.53	4.42	4.53	4.53	0.04	0.07	0.99	0.31
Juiciness	4.82^{Bb}	4.40^{Aa}	4.68^{ABb}	4.43^{Aa}	4.60	4.57	0.04	0.004	0.76	0.60

I* = interaction, TBA = thiobarbituric acid, ΔE = total colour difference

means in the same row with different superscripts significantly differ at $^{a,b}(P \leq 0.05)$ and $^{A,B}(P \leq 0.01)$

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Table 4. Fatty acids pattern of intramuscular fat (g/100 g of all estimated acids), hypocholesterolemic/hypercholesterolemic (h/H) ratio, atherogenic index (AI), thrombogenicity index (TI), peroxidizability index (PI), and iodine value (IV) in *Longissimus thoracis* muscle

	Experimental groups (G) (n = 16 per each group)				Sex (S) (n = 32 per each group)		SEM	P-value		
	control	BHT	hop extract		gilts	barrows		G	S	I*
			500 mg/kg	1000 mg/kg						
C10	0.07	0.08	0.11	0.07	0.07^{a}	0.10^{b}	0.01	0.23	0.04	0.20
C12	0.04^{a}	0.06^{ab}	0.08^{b}	0.07^{ab}	0.06	0.07	0.01	0.02	0.19	0.74
C14	1.17	1.04	0.98	1.04	0.99	1.13	0.05	0.52	0.16	0.22
C16	23.97^{C}	22.54^{BC}	21.02^{AB}	19.33^{A}	21.18	22.25	0.43	< 0.001	0.14	0.12
C16:1	2.12^{a}	2.15^{a}	2.62^{b}	2.11^{a}	2.10^{a}	2.40^{b}	0.07	0.015	0.02	0.21
C18	11.55^{B}	10.98^{AB}	10.32^{A}	11.48^{B}	10.93	11.23	0.15	0.009	0.28	0.85
C18:1	44.95	45.16	45.50	46.18	45.09	45.80	0.30	0.50	0.25	0.99
C18:2	12.22	12.74	13.47	12.90	13.99^{B}	11.68^{A}	0.39	0.68	0.002	0.17
C 18:3 n-3	0.48^{A}	1.17^{B}	1.26^{B}	1.28^{B}	1.09	1.00	0.05	< 0.001	0.052	0.27
C 18:3 n-6	0.09^{A}	0.12^{B}	0.13^{B}	0.12^{B}	0.13^{B}	0.10^{A}	0.01	0.003	0.003	0.18
C20	0.08^{A}	0.08^{A}	0.08^{A}	0.16^{B}	0.10	0.09	0.01	< 0.001	0.45	0.39
CLA 9*t*	0.13^{B}	0.11^{A}	0.11^{A}	0.13^{B}	0.13^{B}	0.11^{A}	0.01	0.003	0.005	0.46
CLA 10*t*	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.32	0.10	0.16
CLA 9*c*	0.14	0.31	0.29	0.34	0.26	0.27	0.01	< 0.001	0.62	0.62
CLA T9*t*	0.79^{ab}	0.70^{a}	0.68^{a}	0.82^{b}	0.72	0.78	0.02	0.02	0.09	0.44
C20:4	1.91^{A}	2.31^{A}	2.32^{A}	3.00^{B}	2.62^{B}	2.14^{A}	0.11	0.001	0.001	0.23
C22:1	0.01^{Aa}	0.02^{ABb}	0.03^{BCc}	0.04^{Cc}	0.03	0.02	0.01	< 0.001	0.54	0.93
EPA	0.20^{Aa}	0.33^{Bb}	0.41^{BCc}	0.45^{Cc}	0.39^{B}	0.31^{A}	0.02	< 0.001	0.01	0.67
DHA	0.063^{Aa}	0.12^{ABb}	0.17^{BCbc}	0.20^{Cc}	0.17^{B}	0.11^{A}	0.01	< 0.001	0.002	0.52
SFA	36.87^{Cc}	34.55^{BCb}	32.56^{Aba}	31.92^{Aa}	33.17^{a}	34.79^{b}	0.44	< 0.001	0.02	0.06
UFA	63.11^{Aa}	65.24^{ABb}	67.01^{Bbc}	67.59^{Bc}	66.73^{b}	64.74^{a}	0.45	< 0.001	0.01	0.15
MUFA	47.08	47.32	48.15	48.33	47.22	48.23	0.31	0.41	0.11	0.91
ΣPUFA	16.03	17.92	18.85	19.25	19.51^{B}	16.51^{A}	0.53	0.08	0.002	0.17
PUFA n-6	15.28	16.30	17.02	17.33	17.87^{B}	15.10^{A}	0.48	0.36	0.002	0.016
PUFA n-3	0.74^{Aa}	1.62^{Bb}	1.84^{Bbc}	1.93^{Bc}	1.65^{B}	1.42^{A}	0.08	< 0.001	0.006	0.43
AI	0.46^{Bc}	0.42^{ABbc}	0.38^{ABab}	0.35^{Aa}	0.38	0.42	0.01	0.006	0.06	0.12
TI	1.10^{Cc}	0.96^{Bb}	0.86^{ABa}	0.83^{Aa}	0.90^{A}	0.98^{B}	0.02	< 0.001	0.01	0.08
h/H	2.41^{Aa}	2.75^{ABab}	2.90^{ABbc}	3.24^{Bc}	2.94	2.71	0.08	< 0.001	0.07	0.23
PI	24.94^{Aa}	29.78^{ABb}	31.66^{Bb}	34.49^{Bb}	32.90^{B}	27.54^{A}	0.99	0.001	0.002	0.21
IV	65.18^{A}	68.29^{AB}	70.48^{B}	70.03^{B}	70.16^{B}	66.83^{A}	0.65	0.005	0.004	0.12

I* = interaction, EPA = eicosapentaenoic acid, DHA = docosahexaenoic acid, SFA = saturated fatty acids, UFA = unsaturated fatty acids, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids

means in the same row with different superscripts significantly differ at $^{a–c}(P \leq 0.05)$ and $^{A–C}(P \leq 0.01)$

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Higher pH (lower acidity) at 24 hours after slaughter could be due to the inhibition of lipolysis by antioxidant supplements and lower fatty acids releasing (Wood et al. 2003). Lower atherogenic and thrombogenicity indexes indicate a health-promoting effect of the hop extract: the lower the index, the less the possibility of atherosclerosis and coronary heart diseases (Ulbricht and Southgate 1991).

According to Gatlin et al. (2002) the fatty acid profile of fat deposited in pigs is similar to that given in the diet, although according to Lopez-Bote and Rey (2001) this concerns mainly adipose tissue. In this experiment the dietary treatment was the same but the fatty acids pattern of intramuscular fat was different. An increased content of unsaturated fatty acids creates meat with beneficial health properties but susceptible to oxidation. On the other hand, the hop supplement effectively reduced this process, which is confirmed by a significantly lower TBA level after two weeks and even further after 6 months of storage. A similar, though non-significant, improvement of meat stability was obtained using nettle extract (Hanczakowska et al. 2007b). The iodine value increased by the extract ranged in a limit appropriate for meat shelf life and processing (Benz et al. 2011).

According to Wood and Enser (1997) an antioxidant supplement in the fatteners' feed can improve the fatty acids profile of meat and prevent oxidative changes occurring during storage and cooking. Unfortunately this positive opinion has not been checked in the present experiment. While the odour and taste of meat from pigs fed a lower dose of extract were comparable to those of the control groups, a higher amount of extract gave worse results. As hop is a popular raw material in beer production, mainly due to its specific smell and bitter taste (Zanoli and Zavatti 2008), it is possible that the higher dose lowered its acceptance. We also encountered worse results when a higher level of extract from cone flower was used in pig feed (Hanczakowska and Swiatkiewicz 2007).

Summing up the results, it can be concluded that the extract from hop did not affect the pig's performance but improved the quality of meat and its health-promoting properties. A high dose of hop extract in feed mixture may decrease the sensory traits of meat.

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