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The influence of herbal additives on fattening and carcass performance, blood indices and meat quality in fattening pigs

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The purpose of this study was to evaluate how adding a herbal mixture containing clove oil (*Syzygium aromaticum*), thyme oleoresin (*Thymus vulgaris*) and garlic oil (*Allium sativum*) to fattening pig feed affected the production performance and body homeostasis status of fattening pigs. The study used 20 weaners from three breeds (♀ (landrace × yorkshire) × ♂ duroc) with an initial body weight of about 33.5 kg, divided into two groups: C (control) and E (experimental) (sex ratio 1:1, gilts: barrows). Two-phase fattening was conducted to a weight of about 125 kg. The fatteners were fed ad libitum with complete feed mixes. Group E animals received a herbal supplement of 0.5 kg/1 ton of mix. After fattening and slaughtering, the following parameters were analysed: fattening and slaughter performance, as well as chemical and physical parameters of pork, the proportion of fatty acids and fatty acid groups, AI and TI indices, the level of bioactive peptides and body homeostasis state. The addition of herbs had a positive effect on the quality of the meat obtained from the porkers. The meat was characterized by a darker colour (L), higher protein content, lower fat content, lower WHC and a favourable dietary fatty acid profile (less SFA, more PUFA and lower n6/n3, AI and TI). There was no effect of the herbal supplement on daily gain, quantitative slaughter traits, bioactive peptide levels, or body homeostasis status.

KEYWORDS: fatteners / clove / thyme / garlic / production performance / meat quality / blood indices

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After the introduction of restrictions on the use of antibiotics in animal production and treatment in 2006 [Anadón 2006], natural products became an alternative [Yu *et al.* 2017, Tsiplakou *et al.* 2021]. Herbs and herbal extracts, as well as phytobiotics, whose therapeutic properties have been known for centuries, have begun to be widely used in ongoing research work [Kiczorowska *et al.* 2017, Van der Aar *et al.* 2017, Gheisar and Kim 2018, Kostadinović and Lević 2018].

Phytogenic feed additives (PFAs) are substances of plant origin with a wide spectrum of biological properties: antibacterial, antiviral, antiparasitic, antioxidant, as well as having flavouring effects and supporting immunity [Kostadinović and Lević 2018]. The properties of PFA result from the biologically active components they contain: glycosides, alkaloids, saponins, flavonoids, tannins, pectins and organic acids [Kuralkar and Kuralkar 2021]. Their use reduces the risk of microbial resistance and therefore PFA additives are successfully used in the feeding of many livestock species [Rogosic *et al.* 2015, Ayrle *et al.* 2016, Chen *et al.* 2021, Radzikowski and Milczarek 2021, Makała 2022, Radzikowski and Milczarek 2022].

In intensive production, animals, including pigs, are exposed to oxidative stress, which promotes the occurrence of many diseases. The active substances in herbs can provide a line of defence against physical pathogens and environmental stressors [Bhatt 2015]. The effectiveness of their use is due to improved palatability of feed and stimulation of appetite, as well as modulation of intrinsic processes, including those directly related to animal productivity [Makała 2022]. Feed supplementation with herbal additives, including those from the PFA group, is in line with the modern agricultural concept of organic animal production. Among many herbs and active substances extracted from them, attention has been paid to the usefulness of garlic, clove, and thyme in pig production.

Common garlic (*Allium sativum* L.) is a plant of the garlic family (*Alliaceae*). The essential oil extracted from it contains a variety of pharmacologically important sulphur compounds including diallyl disulfides (DADS) and diallyl trisulfides (DATS) [Cullen *et al.* 2005, Huang *et al.* 2022]. The oil’s effects are multidirectional, including antimicrobial, anti-atherosclerotic, fibrinolytic, platelet aggregation inhibition, blood glucose lowering, antioxidant, anticancer, anti-inflammatory, and immune boosting properties [Cullen *et al*. 2005, Omojola *et al*. 2009, Lawrence and Lawrence 2011, Bocate *et al*. 2021, Huang *et al*. 2022].

Clove oil (*Oleum caryophyllorum*) is an essential oil extracted from clove (*Syzygium aromaticum*), a species of tree in the myrtle family (*Myrtaceae*). Clove contains volatile compounds and antioxidants, and the oil extracted from it exhibits health-important biological activity [Haro-González *et al.* 2021]. Clove oil is an antiseptic, warming and disinfectant, as well as an antimicrobial that inhibits the growth or kills pathogenic microorganisms, such as: *Escherichia coli*, *Mycobacterium phlei*, *Bacillus substilis*, *Streptococcus aureus*, *Aspergillus niger*, *Penicillum chrysogenum* [Nowak *et al*. 2012]. The new results of the study indicate its anti-inflammatory, analgesic, anaesthetic, antinociceptive and antitumor effects [Haro-González *et al.* 2021].

Thyme oleoresin is extracted from the plant known as thyme/ thyme proper/ thyme (*Thymus vulgaris*), a family of the order *Lamiales Bromhead*. It is an oleoresin containing bioactive components and minerals - copper, iron, manganese, with antioxidant, anti-inflammatory and antimicrobial - bacterial and fungistatic activities [Klimiuk *et al.* 2023].

There are many applications of essential oils. Due to their unique chemical composition and properties, they are used in pharmacology, cosmetology, animal husbandry, and the processing of animal raw materials [Mucha and Witkowska 2021]. They are a natural alternative to preservatives, flavour enhancers and antibiotics. When used as feed additives in animal production, essential oils improve feed palatability and increase feed intake, improve animal immunity and health, prevent and treat diseases. They can be used in organic farming. Essential oils improve the safety, hygiene, and quality of food of animal origin. They exhibit antimicrobial effects including antibacterial, immune-stimulating, antioxidant, and anti-inflammatory, improve growth and intestinal health [Omonijo *et al*. 2018, Mucha and Witkowska 2021]. The use of garlic oil as a feed additive for growing pigs is supported by the results of a study by Cheng *et al.* [2023], which indicates its involvement in the regulation of the immune system and its positive association with the composition of the intestinal microbiome of weaned piglets. Similarly, Omonijo *et al*. [2018] found antimicrobial, antioxidant, and anti-inflammatory effects of the oil as well as its positive effect on feed palatability and intestinal growth and health.

There have been studies on the productivity of growing pigs, including blood biochemical indices, immune indices, structure and development, and the gut microbiome, following the use of garlic oil in the feeding of growing pigs conducted by various teams, including Lawrence and Lawrence [2011], Omonijo *et al*. [2018], Bocate *et al*. [2021], and Cheng *et al*. [2023]. Far fewer studies have investigated the effects of herbal additives on meat quality and the results of these studies are inconclusive [Yu *et al*. 2012, Omojola *et al*. 2009, Huang *et al.* 2022]. Su *et al*. [2018] found that using plant essential oils in weaned piglets improved growth performance and immune function, relieved stress and showed antioxidant activity. Also, the authors find the supplement's use economical. Huang *et al*. [2022] improved growth performance and nutrient digestibility supplementing feed for fattening pigs with plant oils.

Based on the properties of thyme, garlic, and clove, and the biological functions of their active compounds, it was hypothesized that they could enhance pig growth and improve slaughter material quality. Therefore, the purpose of this study was to apply a composition of natural extracts of clove, thyme, and garlic to complete feed mixtures for fattening pigs and study the effects of oils on fattening performance, carcass slaughter value, meat quality and body homeostasis status.

Material and methods

The animals were kept on a family farm, and the research material (blood, meat) was collected during and after the pigs were slaughtered. According to Polish law and EU Directive (No. 2010/63/EU), the experiment did not require the approval of the Local Ethical Committee.

Animals and housing system

For the study, 20 weaners from three breeds (♀ (landrace × yorkshire) × ♂ duroc) were used, 10 each in the control (C) and experimental (E) groups (sex ratio 1:1 – gilts: barrows), with an initial body weight of 33.5 kg. At the beginning of the experiment, the pigs were marked with an individual ear tag number, weighed and placed in two pens: C and E. Two-phase fattening was carried out, phase I and II lasting 4 and 6 weeks, respectively. Animals were weighed individually three times: at the beginning of the experiment, after 4 weeks, i.e. at the end of phase I of fattening, and at the end of the experiment. Fattening was completed at an average body weight of about 125 kg. Maintenance conditions for growing animals were in accordance with the Ordinance of the Minister of Agriculture and Rural Development (2010).

Nutrition

The fattening pigs were fed complete feed mixes for the first and second fattening periods (Tab. 1 and 2). In group E, throughout the fattening period, the pigs received with the feed an herbal powder additive at a rate of 0.5 kg per ton of complete mix, consisting of clove oil (*Syzygium aromaticum*), thyme oleoresin (*Thymus vulgaris*) and garlic oil (*Allium sativum*).

The animals were fed ad libitum. Pigs had unlimited access to water.

Slaughter

After fattening, the animals were transported to the slaughterhouse and slaughtered in accordance with current procedures. At slaughter, blood was drawn from all animals. Post-slaughter carcass parameters were evaluated (n = 20): hot carcass weight, thickness backfat and the height of *longissimus dorsi* muscle between the 3rd and 4th rib counting from the last rib, and meatiness. After the carcasses had cooled for 24 hours, samples of the *longissimus lumborum* (*M. longissimus lumborum* - MLL) muscle (about 0.5 kg) were taken from the right half-carcass for qualitative studies.

Blood

Blood was centrifuged immediately after collection (10 minutes, 3500 rpm), and the resulting serum was stored at -20ºC. Determinations of biochemical indices were performed in serum using Cormay's Accent 200 biochemical analyser, using level 1 multicalibrators, HP and HN sera, and Cormay test reagents. Albumin - ALB, total protein - TP, glucose - GLU, cholesterol - CHOL, high-density cholesterol fraction - HDL, creatinine - CREA, urea - UREA were determined.

Table 1. Proportion of feed materials (%) used in complete feed mixes for fattening pigs in groups C and E, during the first and second phases of fattening

Components	Fattening periods	
	I	II
Wheat	25.0	20.0
Triticale	15.0	20.0
Barley	36.6	36.7
Oats	5.0	8.0
Soybean meal	15.0	12.8
Soybean oil	0.4	-
Premix*	3.0	2.5

*Premix composition: lysine – 12.10%; methionine – 2.65%; threonine – 5.05%; tryptophan – 0.25%; calcium – 20.50%; phosphorus – 1.80%; sodium – 5.00%; iron – 4,000 mg; manganese – 2 400 mg; zinc – 2 600 mg; copper – 800 mg; iodine – 55.0 mg; selenium – 13.50 mg; vitamin A – 260,000 IU; vitamin D3 – 69,000 IU; vitamin E – 4 700 mg; vitamin K3 – 68 mg; vitamin B1 – 68 mg; vitamin B2 – 170 mg; vitamin B6 – 105 mg; vitamin B12 – 830 mcg; vitamin C – 1,000 mg; folic acid – 27.00 mg; pantothenic acid – 410 mg; niacinamide B3 – 690 mcg; biotin – 3,450 mg; choline chloride – 10,000 mg; additives: 3c amino acids: L-lysine 3.2.2., L-threonine 3.3.1., DL-methionine 3.1.1., L-tryptophan 3.3.1, L-valine 3.7.1.; Aroma, antioxidant: 1b (E320-BHA, E321-BHT, E324 – Ethoxyquin) 550 mg/kg; Enzymes: 4a E-1 640 6 – phytase (EC 3.1.3.2.6 n-5000 FTU/g) 17 500 FTU/kg, (E1600 endo 1,4-beta-xylanase, EC 3.2.1.8 – 22,000 VU/g; 425,000 VU/kg, endo 1,3 beta-glucanase EC 3.2.1.6 – 30,000 VU/g, 57 000 VU/kg); raw material composition: calcium carbonate, monocalcium phosphate, (monophosphate) sodium chloride 1.8.1.9.

Table 2. Chemical composition of feed mixes (%) for fattening pigs in groups C and E in the first and second phases of fattening

Specification	Fattening periods	
	I	II
Dry matter	87.7	87.6
Total protein	17.1	15.4
Crude fat	2.2	2.2
Crude fiber	3.8	3.9
Crude ash	3.8	4.0
Nitrogen-free extractables – NEF	60.8	62.1
of which starch	45.5	48.9

Analysis of meat

Drip loss was determined according to the following procedure: a sample of meat - about 300 g was placed in a polyethylene bag and kept under refrigeration (+4°C) for 24 hours. After 24 hours, the resulting leakage was decanted, and its amount was expressed as a percentage of the sample weight.

Meat colour analysis was performed in the CIE L*a*b* system with a Chroma Meter CR-400/410 - Konica Minolta, and the hue (b*/a*) and colour saturation (√(a*2+b*2)) of the meat samples were calculated according to the formula given by Mordenti *et al*. [2012].

Freshly milled pork samples were assayed for water, protein, intramuscular fat, and collagen content using a FoodScanTMLab spectrometer from Foos (PN-A 82109 2010).

Water holding capacity (WHC) was determined according to the methodology provided by Grau and Hamm [1952] as modified by Pohja and Ninivarra [1957].

Meat fat extraction was conducted according to Folch [AOAC 2007]. Fatty acid methylation was performed according to the trans-esterification method ISO PN EN 5509 [2000]. Individual fatty acids were identified in crude fat using an Agilent 7890A GC (Agilent, Waldbronn, Germany) according to Puppel *et al*. [2013]. Each peak was identified using pure methyl ester standards: FAME Mix RM-6, Lot LB 68242; Supelco 37 Comp. FAME Mix, Lot LB 68887; Methyl linoleate, Lot 094K1497; CLA Conjugated (9Z, 11E), Lot BCBV3726 (Supel-co, Bellefonte, PA, USA). The following acid groups were determined: SFA – C14:0, C16:0, C17:0, C18:0; MUFA – C16:1, C17:1, C18:1, C20:1, C22:1; PUFA n-6: C18:2, C20:4; PUFA n-3: C18:3, C22:5, C22:6. The determined proportion of fatty acids and fatty acid groups enabled the calculation of indices: AI - atherogenic index and TI - thrombogenic index according to Ulbricht and Southgate [1991].

Levels of bioactive peptides - carnosine, anserine [Łukasiewicz *et al*. 2015], Q10, creatine, creatinine, taurine (Purchas *et al*. 2004) in muscle samples were determined using a high-performance liquid chromatography, reversed phase RP-HPLC Agilent 1100 (Agilent Technologies, Waldbronn, Germany) and Jupiter C18 300A column (Phenomenex, Torrance, CA, USA).

Statistical analysis

The results were processed using the IBM SPSS Statistics 27 package. The normal distribution of the characteristics was checked with the Shapiro-Wilk test. Differences between groups were checked with the Kruskal-Wallis test. The tables show the mean results and standard deviations. Differences were considered statistically significant at $p \leq 0.05$ or $p \leq 0.01$.

Results and discussion

The initial and final body weights of animals in groups E and C were similar ($p>0.05$) - Table 3. The average daily weight gain of fattening animals in both groups throughout the fattening period was more than 1200 g ($p>0.05$).

Consequently, there was no effect of the applied herbal additive based on clove, thyme, and garlic on the daily weight gain. Phytobiotic additives have a sensory function and influence health and productivity. Garlic (*Allium sativum*) contains the active compound allicin with antibacterial, antiviral, and antifungal properties [Cullen *et al*. 2005]. Using its addition at doses of 1g/kg or 10 g/kg of feed, the cited researchers achieved improvements in fattening parameters. Allicin contained in garlic can beneficially modify the gastrointestinal microflora by lowering the negative effects

Table 3. Fattening performance (x̄, SD)

Trait	Groups C	Groups E	*p*-value
Initial body weight (kg)	33.5±1.39	33.4±1.22	0.796
Body weight at the end of I fattening period (kg)	68.1±3.81	66.6±2.99	0.579
Final body weight (kg)	125.5±8.66	125.6±6.82	0.481
Total body weight gain during fattening (kg)	92.0±8.58	92.2±7.33	0.529
Average daily weight gain (g)	1227.0±114	1229.0±98	0.529

of antinutritional substances contained in cereals and pulses, has immunomodulatory effects, reduces the severity of infections and mortality from intestinal disorders [Chen *et al*. 2020, Johnson and Iorliam 2020, Chen *et al*. 2021]. However, despite the above and the proven bacteriostatic effect of clove oil [Nowak *et al.* 2012] and the bacteriostatic and antioxidant effects of thyme [Radzikowski and Milczarek 2021], our herbal supplement did not change the observed basic production rates.

Herbs, mixtures of herbs and phytobiotic additives containing plant extracts or oils have been used in swine feeding and the experiments conducted have involved different technological groups of pigs [Wen-Chao *et al.* 2017, Johnson and Iorliam 2020, Sánchez *et al.* 2020, Rabelo-Ruiz *et al.* 2021]. Most studies conducted on fattening pigs have reported beneficial effects of herbs on appetite and feed intake, as well as productivity - final body weight [Cullen *et al*. 2005, Onyimonyi and Omeje 2013, Chen *et al*. 2020, Samolińska *et al.* 2020]. Except for our research, there are few experiments in which the beneficial effect of the applied phytobiotic supplement on fattening parameters was not confirmed [Oanh *et al*. 2021]. The cited researchers did not note a positive effect on the digestibility and assimilability of nutrients, as well as the body weight and growth rate of the animals in the experiment using a mixture of herbs (60% *Bidens pilosa* L., 15% *Urena lobata* L., 15% *Pseuderanthemum palatiferum*, 5% *Ramulus cinnamomi* and 5% *Illicium verum*) in the diet of fattening pigs. It can be concluded that the composition of herbal mixtures determines a variety of production, physiological and health effects, as well as the specific response from the animal's body.

Pigs in the E vs. C group had 2 mm thicker backfat (p>0.05) and lower height "eye" of loin (1.5 mm) and meatiness (1.3%) (p>0.05) - Table 4.

Table 4. Results of carcass performance (x̄, SD)

Trait	Groups C	Groups E	*p*-value
Hot carcass weight (kg)	96.8±6.9	97.2±6.0	0.436
Thickness of back-fat (mm)	14.9±2.5	16.9±4.8	0.280
Height of "eye" loin (mm)	68.8±6.8	67.3±6.8	0.579
Meatiness (%)	58.9±1.9	57.6±2.8	0.190

In our study, a slight reduction in meatiness and an increase in fatness were noted in fattening pigs receiving the herbal additive (group E vs. C). Conversely, improvements in meatiness and reductions in carcass fat content were noted by

Omojola *et al*. (2009), Grela *et al*. (2013) and Samolinska *et al*. (2020) when giving fatteners feed additives containing garlic. Using powdered herbal extract (carvacrol, trans-cinnamic aldehyde and capsaicin from oregano (*Origanum* spp.), cinnamon (*Cinnamomum* spp.) and black pepper (*Piper nigrum* L.) in the diets of fattening pigs, Olkowski *et al*. (2019) found increased thickness of backfat in fattening pigs. The impact of various herbal additives (0.2–2% in feed) on quantitative slaughter traits remains unclear, regardless of form-fresh, dried, extract, or oil. This may be due to the use of different sets of herbs and/or additives of active substances derived from them, showing synergism or antagonism of action towards each other [Vaou *et al*. 2022].

The levels of several tested biochemical indices (TP, GLU, CREA) of blood showed minor variation between groups with no statistically significant differences (Tab. 5). For ALB, CHOL, CHO-HDL and UREA, the results of the analyses were similar in both groups.

Table 5. Selected blood biochemical indices ($\bar{x}$, SD)

Trait	Groups		*p*-value
	C	E	
Albumin (g/l)	4.4±0.2	4.6±0.5	0.481
Total protein (g/l)	77.7±2.9	76.7±4.4	0.247
Glucose (mmol/l)	13.1±1.6	11.1±2.7	0.520
Cholesterol (mmol/l)	3.0±0.2	3.2±0.5	0.190
HDL cholesterol (mmol/l)	1.3±0.5	1.2±0.2	0.247
Creatinine (µmol/l)	184.5±11.1	196.6±24.4	0.165
Urea (mmol/l)	8.2±1.1	8.3±1.4	0.796

The absence of group differences in blood biochemical indices, along with values within the species' reference range, suggests normal metabolism in the studied pigs. [Czech *et al.* 2018, Winnicka 2021]. Determination of biochemical and haematological parameters of blood is one of the ways to assess animal health and welfare [Marco-Ramell *et al*. 2016]. The values of these parameters depend, in part, on the quantity and quality of feed ingredients, and may be affected by the feed additives used in the feeding of growing pigs [Klimiuk *et al*. 2023]. Our results confirm the good health and welfare of the animals participating in the test.

In an experiment reported by Oanh *et al*. [2021], feeding fattening pigs a herbal mixture reduced red blood cell count, cholesterol, urea nitrogen, and low-density lipoproteins. At the same time, the study reported no effect of the additive used on the growth characteristics of the animals. On the other hand, Ismail *et al.* [2021], Huang *et al.* [2022], Abd El Ghany [2024] point to the beneficial effects of garlic and garlic oil on haematological parameters and their hypocholesteric effects, emphasizing that lower serum and liver cholesterol levels inhibit bacterial growth. According to Gümüs *et al*. [2017], thyme essential oils at a dose of 300, 450 mg/kg can minimize lipid oxidation and have a positive effect on blood lipid profile. Positive results for redox status and blood lipid profile were also reported by Klimiuk *et al*. [2023]. A diet containing thyme herb at 3% or 1% had a beneficial effect on the lipid metabolism of fattening pigs, causing a reduction in cholesterol and its LDL fraction, as well as TG. The main active substances in thyme oil that inhibit the activity of the enzyme that regulates endogenous cholesterol biosynthesis are carvacrol and thymol [Elson 1995]. Shao *et al*. [2023] found a reduction in TG, total cholesterol and its LDL-C and HDL-C fractions using a mixture containing carvacrol and thymol as well as cinnamaldehyde in the diets of weaned piglets. Favourable changes in blood lipid indices have been observed in Japanese quails, broiler chickens, and calves fed diets enriched with thyme essential oil [El-Ghousein and Al-Beitawi 2009, Khaksar *et al*. 2012, Seirafy and Sobhanirad 2017].

The meat of the fattening animals in the experimental group, compared to the control group, contained more protein (p=0.001), and less intramuscular fat (IMF) (p≤0.05) - Table 6. Meat from animals in this group was darker (p=0.001), while in hue and colour saturation it did not differ from meat from group C. Drip loss was comparable in groups E and C, while the water holding capacity (WHC) was better in group E compared to C - the difference was 3.65 cm^2/g (p=0.001).

Table 6. Quality of the *longissimus lumborum* muscle ($\bar{x}$, SD)

Trait	Groups		*p*-value
	C	E	
Water (%)	72.08 ±0.66	72.46±0.68	0.280
Collagen (%)	0.98±0.25	1.15±0.28	0.165
IMF (%)	3.24±0.72	2.57±0.71	0.035
Protein (%)	23.08±0.24	23.78±0.52	0.001
L*	52.69±1.26	50.36±1.38	0.001
a*	7.32±1.28	8.11±1.27	0.315
b*	4.45±1.46	4.85±0.96	0.736
Shade	0.60±0.15	0.60±0.08	0.481
Colour saturation	4.82±0.55	5.08±0.40	0.393
Drip loss (%)	3.84±1.37	4.12±1.21	0.739
Water holding capacity (cm^2/g)	20.42±1.50	16.77±1.56	0.001

Obtaining pork with a higher protein content and proportion of PUFA n-3 and a lower proportion of SFA and total fat in LL muscle (group E vs. C in our own study) should be considered beneficial in terms of the needs and health of the consumer, interested in purchasing lean meat. The fat content of 2.57% in LL muscle, obtained from pigs receiving the phytobiotic additive, is characteristic of quality meat [Wood *et al*. 2008]. Olkowski *et al*. [2019] obtained results on fatness and IMF content in meat from fattening pigs fed with herbs that are consistent with and confirm the results of our study. The cited authors found an increase in carcass fatness and a decrease in intramuscular fat (IMF) content in the *longissimus lumborum* muscle.

There were no statistically significant differences between the E and C groups in the content of health-promoting fatty acids: C 18:2. C 18:3. C 20:4. C 22:1. C 22:5 (Tab. 7). The content of C 22:6 in pork increased significantly. The differences between groups were found to be significant (p≤0.05). The proportion of saturated fatty acids in the total profile was significantly lower (p=0.001), while for monounsaturated higher

Table 7. Fatty acid content of the lipid fraction of the *longissimus lumborum* muscle (mg/g muscle)

Trait	Groups		*p*-value
	C	E	
C 14:0	1.23 ± 0.10	0.84 ± 0.340	0.026
C 16:0	26.02 ± 0.99	20.04 ± 4.08	0.001
C 16:1	2.84 ± 0.40	5.25 ± 1.21	0.001
C 17:0	0.48 ± 0.29	0.10 ± 0.11	0.012
C 17:1	0.16 ± 0.05	0.41 ± 0.32	0.050
C 18:0	12.93 ± 1.47	8.17 ± 1.79	0.001
C 18:1	47.57 ± 1.61	44.76 ± 2.76	0.018
C 18:2	2.67 ± 0.51	2.55 ± 1.03	0.328
C 18:3	0.17 ± 0.07	0.22 ± 0.12	0.181
C 20:1	0.45 ± 0.27	0.14 ± 0.17	0.036
C 20:4	0.40 ± 0.24	0.49 ± 0.29	0.689
C 22:1	0.22 ± 0.24	0.42 ± 0.38	0.113
C 22:5	0.08 ± 0.05	0.12 ± 0.07	0.272
C 22:6	0.06 ± 0.02	0.11 ± 0.05	0.026

Table 8. Content of selected fatty acid families in the MLL lipid fraction and health-promoting indicators

Trait	Groups		*p*-value
	C	E	
SFA	42.47±1.07	34.61±5.28	0.001
MUFA	53.5 ±1.17	60.88±4.56	0.001
PUFA	3.54±0.61	4.19±1.77	0.346
PUFA n6	3.21±0.56	3.65±1.68	0.814
PUFA n3	0.33±0.10	0.54±0.16	0.025
Other	0.46±0.16	0.32±0.09	0.126
n6/n3	10.36±2.79	6.91±2.33	0.025
AI	0.57±0.02	0.43±0.09	0.002
TI	1.43±0.06	1.03±0.23	0.001

(p=0.001) in the E *vs.* C group (Tab. 8). The proportion of PUFA n-3 in the meat of fattening pigs in group E *vs*. C was higher (p≤0.05), and the ratio of PUFA n-6 to PUFA n-3 was narrower (p≤0.05). The values of health-promoting indices AI and TI differed between the control and experimental groups (p≤0.01), in favour of group E.

In our study, AI and TI index values were lower in the E *vs* C group (p<0.01). These results are beneficial health-wise, as supported by the data presented in Ghaeni *et al.* [2013]. The main saturated fatty acids (including C14:0 myristic and C16:0 palmitic), are considered proatherogenic - promoting lipid adhesion to immune and blood cells; their contribution to the profile was lower in the E *vs* C group. C18:0 stearic acid is considered thrombogenic [Attia *et al.* 2017], and unsaturated fatty acids, especially n-3, have anti-atherosclerotic effects [Ghaeni *et al.* 2013]; the proportion of n-3 PUFAs in the profile was higher in our study, which should be considered health beneficial. The PUFA n-6/n-3 ratio was more favourable in the E group than in the C group, though it remained above the health-desirable level of 4, as reported by Wood *et al.* [2008]. In Klimiuk *et al.* [2023], after supplementation with 3% thyme, the n-3 PUFA content increased and the SFA content decreased significantly. Thyme was found to have a positive effect on redox status and muscle lipid profile. The use of the herbal supplement in our study had a beneficial effect on the content and profile of fatty acids from the point of view of consumer needs and health.

The results obtained in terms of the content of bioactive compounds determined in the experiment were mostly comparable between the two research groups (Tab. 9), only the content of carnosine was slightly higher in the meat of pigs from the E *vs.* C group ($p>0.05$).

Table 9. Content of selected bioactive compounds in the *longissimus lumborum* muscle (mg/g)

Trait	Groups		*p*-value
	C	E	
Q10	0.06±0.02	0.06±0.02	0.681
Anserine	0.33±0.10	0.32±0.10	0.996
Carnosine	2.47±0.49	2.85±0.97	0.470
Creatine	2.03±0.25	2.03±0.28	0.918
Creatinine	1.06±0.24	1.09±0.24	0.681
Taurine	0.20±0.03	0.21±0.03	0.470

The meat obtained from fattening pigs in our research can be considered a useful source of bioactive substances [Pravst *et al.* 2010, Sońta *et al.* 2022]. The content of bioactive compounds was comparable in the samples studied with the results reported by the cited researchers for pork: creatine (247-347 mg/100 g), carnosine (211-419 mg/100 g), taurine (50-72 mg/100 g), coenzyme Q10 (about 2 mg/100 g). Such bioactive substances as L-carnitine, coenzyme Q10, carnosine, anserine, taurine, creatine, glutathione, alpha lipoic acid, conjugated linoleic acid (CLA) are potentially beneficial to human health. The biologically active substances contained in pork have been shown to have positive effects on: heart function (taurine), brain function (creatine), muscle function (creatine, taurine, creatinine), regulate metabolism, have antioxidant effects (anserine, carnosine, coenzyme Q10), anti-carcinogenic effects, support digestion (taurine), lower blood pressure and blood glucose levels, reduce metal ion toxicity (carnosine), slow down the aging processes of the body (carnosine, anserine) [Prasow *et al.* 2019], which fully justifies the consumption of pork. Although meat and its products are counted among high-risk diets, meat components such as imidazole dipeptides - anserine and carnosine - have bioregulatory functions. According to Kajiya *et al*. [2023], cooking not only increases their amount but also supports their antioxidant activity, in addition, anserine increases nitric oxide production in vascular endothelial cells. This information is valuable for health-conscious consumers and allows for the development of high-quality functional meat products.

Conclusions

Based on the results, it should be concluded that the addition of a 0.05% composition of natural extracts of clove, thyme, and garlic to complete mixes for fattening pigs had a positive effect on meat quality. The meat was darker (L), had higher protein content, lower fat content, better WHC and a favourable dietary fatty acid profile (less SFA, more PUFA, lower n6/n3, AI and TI). There was no effect of the herbal additive on daily gain, quantitative slaughter traits, or body's homeostasis status.

Disclosures

The authors declare no conflicts of interest.

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