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# Utilization of selected organic acids and their mixtures in feeding of broiler chickens

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**The aim of this study was to determine the effect of an addition of medium chain fatty acids (MCFA), calcium butyrate, benzoic acid and their mixtures as potential growth promoters in feeding of broiler chickens. The experiment was conducted on 12 groups of birds fed with the diets containing an addition of benzoic acid – B (0.1%), calcium butyrate – CB (1%), medium chain fatty acids (MCFA): caproic – K1 (0.85%), caprylic – K2 (0.85%) and capric – K3, as well as their mixtures (0.85%) at the 1:1:1 ratio – MCFA (0.85%) and a mixture of capric and caprylic acids in the form of triglycerides (0.3%) applied at the 1.4:1 ratio – MCT. The positive control (PC) included an addition of a coccidiostatic, salinomycin, administered in the quantity of 70 mg/kg. In the negative control (NC) the feed ration did not contain any additives. In all the periods of broiler chicken rearing no improvement in performance results was observed in relation to PC and NC ($P<0.05$). In the period from 1 to 14 days, groups BK2 and BMCFA were characterized by the worst body weight gains, while the highest feed conversion ratio (FCR) was recorded in group BMW ($P<0.05$). In the period from 15 to 35 days the birds from group MWMCFA were characterized by the worst body weight gains and the least advantageous FCR values ($P<0.05$). In the case of the BMCFA, BMCT and BMW groups respective FCR values also increased ($P<0.05$). During the entire period of the experiment (days 1-35 of life) a deterioration in body weight gains of the birds was observed in group BMCFA, whereas a negative effect of supplementation with additives on feed conversion ratios was observed in the birds from the BMW , BMCT, BMCFA and MWMCFA groups (at $P<0.05$).**

**KEY WORDS: organic acids / salinomycin / broiler chickens**

The implemented ban on the application of antibiotics as growth promoters (AGPs) in the diet for poultry and pigs has resulted in the deterioration of rearing results, while simultaneously an increase has been recorded in the use of therapeutic antibiotics widely applied in human medicine, e.g. sulphonamides, tetracyclines and aminoglycosides [6]. The main argument contributing to the withdrawal of these compounds from animal production practice was connected with the threat of cross-resistance developing in bacteria colonising the

alimentary tract of farm animals, which as a consequence may lead to reduced efficacy of antibiotics in human medicine [1]. Among the currently available potential substitutes for AGPs (e.g. probiotics, prebiotics, phytobiotics, organic acids), it is the latter group that is one of the most frequently used alternatives [8, 16]. The use of organic acids presents many advantages, e.g. their antibacterial properties do not induce resistance in bacteria and they also reduce the buffering capacity of the diet. At present practically no reports are available to show their negative effect on human health [3, 5]. Apart from their numerous advantages, some of these acids also have some drawbacks. They promote a reduction in growth rate at the simultaneous increase in feces water content (malic and gluconic acids) [2]. It was found that an addition of benzoic acid to broiler chicken diets at an amount ranging from 0.2 to 0.75% results in growth inhibition. In contrast, supplementation at 0.1% causes no deterioration of rearing results while simultaneously reducing the counts of potentially pathogenic Enterobacteriaceae in the alimentary tracts of chickens [10, 11]. Comparable bactericidal properties are exhibited by medium chain fatty acids (MCFA), such as capronic, caprylic and capric acids [7, 9], as well as butyric acid [23]. The mechanism of their action is complex and has not been thoroughly elucidated to date. It is assumed that the above-mentioned compounds penetrate into bacterial cells in the undissociated form. Next these acids are dissociated, thus promoting an increase in the concentration of hydrogen ions [18]. As a result of the reduced intracellular pH bacterial enzymes are deactivated, leading to bacterial cell death [24]. Butyric acid as a feed additive may be found in the form of calcium, magnesium or zinc butyrate. Butyric acid content in calcium butyrate is 75% [13]. In poultry feeding fatty acids may be applied in the form of medium chain fatty acids as medium chain triglycerides (MCT), since they have a positive effect of fat digestibility [21]. A relatively short carbon chain promotes faster absorption and metabolisation of MCT, which reduces the potential formation of fat deposits [22]. However, available scientific literature on the subject lacks information confirming the positive effect of medium chain fatty acids and their mixtures on rearing results of broiler chickens. For this reason the aim of these investigations was to determine the effect of medium chain fatty acids (MCFA), i.e. caproic, caprylic and capric acids, as well as benzoic acid and their mixtures on rearing results of broiler chickens fed provocation diets.

## Material and Methods

The experiment was conducted on 960 one-day old cockerel chicks (ROSS 308). Cockerel chicks were assigned at random to twelve experimental groups, with 10 replications in each. Birds were kept on straw bedding in brooders of 0.5 $m^2$ at a stocking rate of 16 chicks per 1 $m^2$. No feed additives were administered in the negative control (NC), while in the positive control (PC) a coccidiostatic (salinomycin) was applied at 70 mg/kg. In the other groups the NC diet was supplemented with various organic acids, calcium butyrate (MW) and medium chain fatty acids in the form of triglycerides (MCT). In group III the diet contained an addition of benzoic acid (at 0.1%) – B. In group IV the diet was enriched with calcium butyrate (1%) – MW. The diet of group V contained a mixture of capric and caprylic acids added in the form of triglycerides (0.3%) at a 1.4:1 ratio – MCT. The diet of

group VI contained a mixture of benzoic acid (0.1%) and calcium butyrate (1%) – BMW; group VII contained a mixture of benzoic acid (0.1%) and caproic acid (0.85%) – BK1; group VIII – a mixture of benzoic acid (0.1%) and caprylic acid (0.85%) – BK2; group IX – a mixture of benzoic acid (0.1%) and capric acid (0.85%) – BK3; group X – a mixture of benzoic acid (0.1%) and a mixture of capric and caprylic acids in the triglyceride form (0.3%) at a 1.4:1 ratio – BMCT; group XI – a mixture of benzoic acid (0.1%) and medium chain fatty acids (0.85%) at a 1:1:1 ratio – BMCFA; while group XII contained a mixture of calcium butyrate (1%) and medium chain fatty acids (0.85%) at a 1:1:1 ratio – MWMCFA. Feeds used in the experiment were produced at the Gorzyń Animal Nutrition Experimental Station, belonging to the Poznań University of Life Sciences. These feeds were prepared using a SK2500 plate mill by SKIOLD and an H710/3 horizontal feed mixer by ZUPTOR. Originally the compound feeds before the addition of the tested organic acids did not contain them in their formulation. The feeds were administered *ad libitum* in the powder form. In the period from days 1 to 14 it was starter feed, while in the period from day 15 to day 35 it was grower feed. In this experiment for each period (starter vs. grower feeding) four types of feeds were used (Table 1). Three compound feeds were supplemented with an addition of calcium butyrate. Compound feed 1 was fed to the NC, PC, B, MCT, BK1, BK2, BK3, BMCT and BMCFA groups; compound feed 2 was administered for group MW; compound feed 3 – group BMW; and compound feed 4 – group MWMCFA, respectively. Feed intake (FI) and body weight were recorded at days 14 and 35 of the experiment. For the same periods body weight gain (BWG) and feed conversion ratio (FCR) were also calculated. Results were subjected to one-way analysis of variance (ANOVA) followed by the Duncan test. The analyses were conducted using the SAS 9.1.3 statistical software package (1996). Statistical significance was established at $P \leq 0.05$.

**Results and Discussion**

Rearing results of broiler chickens are presented in Table 2. No improvement of rearing indicators was observed in any of the three rearing periods in relation to PC and NC ($P<0.05$). In the period from day 1 to day 14 the lowest weight gain was recorded for groups BK2 and BMCFA, while the highest feed conversion ratio was observed in group BMW ($P<0.05$). In the period from day 15 to day 35 the lowest weight gain and the highest feed conversion ratio per 1 kg b.m. were recorded for birds from group MWMCFA, while in the case of groups BMCFA, BMCT and BMW an increase was recorded in the feed conversion ratio ($P<0.05$). Throughout the period of the experiment (from days 1 to 35 of life) a deterioration was observed in the body weight gains of birds in group BMCFA, whereas a negative effect of additives on feed conversion ratios was recorded in groups BMW, BMCT, BMCFA and MWMCFA ($P<0,05$).

In the first period of chicken rearing (days 1-14) no positive effect on body weight gains of birds was found ($P<0.05$) for the applied organic acids. Similarly, no statistically significant differences were recorded between the negative control (NC) and the positive

**Table 1**
Participation of components (%) and feeding value of mixtures employed in the experiment

| Specification | Diets | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Starter (1-14 day) | | | | Grower (15-35 day) | | | |
| | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** |
| Wheat | 28.32 | 27.1 | 26.8 | 24.99 | 32.8 | 31.4 | 31.22 | 29.5 |
| Barley | 25.0 | 25.0 | 25.0 | 25.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| Soybean meal 46%* | 25.5 | 25.74 | 25.84 | 26.3 | 17.32 | 17.7 | 17.7 | 18.17 |
| Rapeseed meal 34%* | 6.0 | 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Fish meal 70%* | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Beef tallow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Lard | 6.0 | 6.4 | 6.5 | 7.0 | 5.9 | 6.32 | 6.4 | 6.9 |
| Premix | 1.01[II] | 1.0[II] | 1.0[II] | 1.0[II] | 1.0[III] | 1.0[III] | 1.0[III] | 1.0[III] |
| Monocalcium phosphate | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Limestone | 0.42 | – | – | – | 0.4 | – | – | – |
| $Na_2CO_3$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| NaCl | 0.26 | 0.26 | 0.26 | 0.26 | 0.2 | 0.2 | 0.2 | 0.2 |
| DL-methionine | 0.21 | 0.21 | 0.21 | 0.21 | 0.15 | 0.15 | 0.15 | 0.15 |
| L-lysine HCL | 0.26 | 0.26 | 0.26 | 0.26 | 0.2 | 0.2 | 0.2 | 0.2 |
| L-threonine | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Calculated nutritive value | | | | | | | | |
| ME (MJ) | 12.8 | | | | 13.1 | | | |
| crude protein (%) | 22.0 | | | | 19.0 | | | |
| lysine (%) | 1.43 | | | | 1.16 | | | |
| met+cys (%) | 0.96 | | | | 0.81 | | | |
| Ca (%) | 0.86 | | | | 0.83 | | | |
| P available (%) | 0.42 | | | | 0.41 | | | |

**Diets: 1** – groups: **PC** – positive control (salinomycin 70 mg/kg); **NC** – negative control; **B** – benzoic acid (0.1%); **MCT** – mixture of capric and caprylic acid in form of triglycerides (0.3%) (1.4:1); **BK1** – benzoic acid (0.1%) + caproic acid (0.85%); **BK2** – benzoic acid (0.1%) + caprylic acid (0.85%); **BK3** – benzoic acid (0.1%) + caproic acid (0.85%); **BMCT**

– benzoic acid (0.1%) + mixture capric and caprylic acid in form of triglycerides (0.3%) (1.4:1); **BMCFA** – benzoic acid (0.1%) + medium chain fatty acids (1:1:1) (0.85%); **2** – group **MW** – calcium butyrate (1%); **3** – group **BMW** – benzoic acid (0.1%) + calcium butyrate (1%); **4** – group **MWMCFA** – calcium butyrate (1%) + medium chain fatty acids (1:1:1) (0.85%) [II]vit. A 12000 IU, wit. $D_3$ 3000 IU; vit. E 35 mg, vit. K 2,5 mg, vit. $B_1$ 3 mg, vit. $B_2$ 6 mg, vit. $B_6$ 8 mg, vit. $B_{12}$ 0.03 mg, niacin 30 mg, D-pantothenic acid 15 mg, folic acid 2 mg, biotin 1 mg, choline 200 mg, betaine 125 mg [III]vit. A 10000 IU, vit. $D_3$ 2400 IU, vit. E 30 mg, vit. K 2 mg, vit. $B_1$ 2 mg, vit. $B_2$ 5 mg, vit. $B_6$ 5 mg, vit. $B_{12}$ 0.03 mg, niacin 24 mg, D-pantothenic acid 17.4 mg, folic acid 0.8 mg, biotin 0.8 mg, choline 200 mg, betaine 100 mg *crude protein content in protein component (%)

control (PC). In turn, in group BK2 an addition of a mixture of benzoic acid (0.1%) and caprylic acid (0.85%) resulted in a deterioration of body weight gains ($P<0.05$). In group B, in which benzoic acid was the only additive (0.1%), no negative effect of this acid on body weight gains of chickens was observed. Similarly, a lack of a negative effect for the application of benzoic acid at 0.1% was reported by Józefiak et al. [11] in their study on broiler chickens and by Kluge et al. [12] in an experiment conducted on piglets. In view of the above, it may be stated that caprylic acid could have been a factor causing deterioration in body weight gains in group BK2. Various publications indicate a negative effect of this acid on feed intake, which may obviously result in a decrease in body weight gains of chickens [4, 17]. Nevertheless, results of various studies conducted on several animal species, including chickens, indicated no toxicity of medium chain fatty acids, including also caprylic acid, administered either orally or parenterally [20]. A reduction of body weight gains was also found in group BMCFA both in the period up to day 14, and that up to day 35. The diet in that group, apart from benzoic acid, contained also a mixture of medium chain fatty acids found at a 1:1:1 ratio. Among other acids, MCFA included e.g. caprylic and caproic acids. According to Cave [4], the above-mentioned acids have a negative effect on feed intake in broiler chickens and - similarly as in group BK2 - they may have resulted in a deterioration of body weight gains in broiler chickens. An addition of a mixture of medium chain fatty acids was also used in group MWMCFA and in that group a reduction in body weight gains was also observed in the period from days 15 to 35. In that group the diet included an addition of calcium butyrate (1%). However, it is assumed that calcium butyrate may not have adversely affected this parameter causing its deterioration, since in comparison to group MW, in which only calcium butyrate was added to the feed, no negative effect was observed on body weight gains. These results are consistent with those presented in their study by Leeson et al. [13]. Thus it may be assumed that - similarly as in group BMCFA - a mixture of medium chain fatty acids may have caused a decrease in body weight gains of chickens. In the other groups (B, MW, MCT, BMW, BK1, BK3, BMCT) no significant effect of feed additives was found on body weight gains of chickens.

Analyses of feed intake levels in all the periods in most cases showed no statistically significant effect of the applied experimental factors. A reduction of feed intake was recorded only in groups BK2 and BMCFA in the period from day 1 to day 14 and this re-

**Table 2**
Effect of medium-chained fatty acids (MCFA), benzoic acid and their mixtures on basic parameters of rearing the chickens

| Indicators | PC | NC | Groups | | | | | | | | | | SEM | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | B | MW | MCT | BMW | BK1 | BK2 | BK3 | BMCT | BMCFA | MWMCFA | | |
| **BWG (g)** | | | | | | | | | | | | | | |
| 1-14 day | 421$^{abc}$ | 427.5$^{ab}$ | 416$^{abc}$ | 433$^{a}$ | 419$^{abc}$ | 400$^{bcd}$ | 410$^{abcd}$ | 396$^{cd}$ | 425$^{abc}$ | 424$^{abc}$ | 382$^{d}$ | 435$^{a}$ | 26.026 | 0.003 |
| 15-35 day | 1435$^{a}$ | 1353$^{ab}$ | 1337$^{ab}$ | 1402$^{ab}$ | 1379$^{ab}$ | 1348$^{ab}$ | 1355$^{ab}$ | 1350$^{ab}$ | 1403$^{ab}$ | 1408$^{ab}$ | 1295$^{ab}$ | 1265$^{b}$ | 125.560 | 0.293 |
| 1-35 day | 1856$^{a}$ | 1781$^{ab}$ | 1753$^{ab}$ | 1835$^{a}$ | 1798$^{ab}$ | 1748$^{ab}$ | 1765$^{ab}$ | 1746$^{ab}$ | 1827$^{ab}$ | 1832$^{ab}$ | 1676$^{b}$ | 1700$^{ab}$ | 132.965 | 0.197 |
| **FI (g)** | | | | | | | | | | | | | | |
| 1-14 day | 548$^{abc}$ | 569$^{ab}$ | 534$^{bcd}$ | 562$^{abc}$ | 537$^{bcd}$ | 569$^{ab}$ | 532$^{bcd}$ | 529$^{cd}$ | 551$^{abc}$ | 581$^{a}$ | 505$^{d}$ | 572$^{ab}$ | 33.998 | 0.001 |
| 15-35 day | 2412 | 2355 | 2356 | 2334 | 2367 | 2443 | 2391 | 2311 | 2430 | 2485 | 2381 | 2333 | 195.612 | 0.861 |
| 1-35 day | 2960 | 2924 | 2890 | 2896 | 2903 | 3013 | 2923 | 2840 | 2982 | 3066 | 2885 | 2905 | 205.402 | 0.699 |
| **FCR** | | | | | | | | | | | | | | |
| 1-14 day | 1.30$^{b}$ | 1.34$^{ab}$ | 1.29$^{b}$ | 1.30$^{b}$ | 1.28$^{b}$ | 1.43$^{a}$ | 1.30$^{b}$ | 1.34$^{ab}$ | 1.30$^{b}$ | 1.38$^{ab}$ | 1.32$^{b}$ | 1.32$^{b}$ | 0.090 | 0.089 |
| 15-35 day | 1.68$^{c}$ | 1.74$^{bc}$ | 1.77$^{abc}$ | 1.67$^{c}$ | 1.72$^{bc}$ | 1.82$^{ab}$ | 1.77$^{abc}$ | 1.71$^{c}$ | 1.74$^{bc}$ | 1.77$^{abc}$ | 1.85$^{a}$ | 1.85$^{a}$ | 0.092 | 0.001 |
| 1-35 day | 1.59$^{d}$ | 1.64$^{bcd}$ | 1.65$^{abcd}$ | 1.58$^{d}$ | 1.62$^{cd}$ | 1.73$^{a}$ | 1.66$^{abcd}$ | 1.63$^{cd}$ | 1.64$^{cd}$ | 1.67$^{abc}$ | 1.73$^{a}$ | 1.71$^{ab}$ | 0.068 | 0.0001 |

Groups: **PC** – positive control (salinomycin 70 mg/kg); **NC** – negative control; **B** – benzoic acid (0.1%); **MW** – calcium butyrate (1%); **MCT** – mixture of capric and caprrylic acid in form of triglycerides (0.3%) (1.38:1); **BMW** – benzoic acid (0.1%) + calcium butyrate (1%); **BK1** – benzoic acid (0.1%) + caproic acid (0.85%); **BK2** – benzoic acid (0.1%) + caprylic acid (0.85%); **BK3** – benzoic acid (0.1%) + caproic acid (0.85%); **BMCT** – benzoic acid (0.1%) + mixture capric and caprylic acid in form of triglycerides (0.3%) (1,4:1); **BMCFA** – benzoic acid (0.1%) + medium-fatty acids (1:1:1) (0.85%); **MWMCFA** – calcium butyrate (1%) + medium chain fatty acids (1:1:1) (0.85%) **BWG** – przyrost masy ciała – body weight gain; **FI** – spożycie paszy – feed intake; **FCR** – współczynnik zużycia paszy na 1 kg masy ciała – feed conversion ratio

sulted in a deterioration of body weight gains in broiler chickens. In both groups the feeds were supplemented with an addition of benzoic acid (at 0.1%), whereas feed in group BK2 additionally contained caprylic acid (0.85%), while in group BMCFA it was a mixture of medium chain fatty acids. As it results from various publications [4, 17], caprylic acid and a mixture of medium chain fatty acids significantly reduce feed intake. It is assumed that these acids stimulate the secretion of cholecystokinin as well as other intestinal hormones responsible for the sensation of satiety, which as a consequence may lead to a decrease in feed intake levels [14, 15]. This hypothesis has not been confirmed, since it was claimed in some studies that the above-mentioned acids have a limited effect on the secretion of cholecystokinin [19]. In turn, benzoic acid may have been a factor deteriorating feed intake levels in group BK2. Although the addition of benzoic acid had not statistically significant effect on the deterioration of feed intake, a negative trend was nevertheless observed (P=0.001) in feed intake. Other evidence confirming this hypothesis is provided by the fact that group BK2 does not differ statistically from group B, in which benzoic acid was the only applied additive. Similar trends showing a decrease in feed intake levels in relation to the control were presented in their study by Józefiak et al. [11]. While the authors of that paper did not give the results concerning feed intake by chickens, based on the presented values of feed conversion ratio (FCR) it may be established that in the group with a 0.1% addition of benzoic acid feed intake was lower in comparison to the control. As a consequence it was reflected in a significant reduction of feed conversion ratio, at a lack of significant differences in body weight gains of broiler chickens. Unfortunately, available literature lacks information verifying the mechanism of the probable negative effect of benzoic acid on feed intake. In the other periods (days 15-35, days 1-35) in the case of all the experimental groups, including groups BK2 and BMCFA, the administered organic acid supplementation was found to have no effect on feed intake in comparison to the controls.

In group BMW the addition of a mixture of benzoic acid (0.1%) with calcium butyrate (1%) caused an increase in the feed conversion ratio per 1 kg b.m. (FCR) in all the rearing periods when compared to PC. In turn, an increase in the feed conversion ratio (FCR) in relation to NC in group BMW was recorded only in the periods from day 15 to day 35 and from day 1 to day 35. Despite the increase in the values of FCR in group BMW, no deterioration was observed in the values of that rearing index in the case of group B, receiving only a 0.1% addition of benzoic acid, and group MW with a 1% addition of calcium butyrate in relation to both controls (PC, NC). However, the negative effect of these compounds was not confirmed in other publications [11, 12]. It may be assumed that the only effect resulting from the addition of these two compounds may have contributed to an increase in FCR, since negative trends may be found for body weight gains and feed intake, which were recorded in broiler chickens from that group (BMW). A lack of a positive effect on feed conversion ratio was also observed in group BMCT in the period from day 1 to day 35. The addition of benzoic acid (0.1%) and a mixture of capric and caprylic acids administered in the triglyceride form (0.3%) at a 1.4:1 ratio had a negative effect on feed conversion ratio (FCR) in comparison to the control with the use of salinomycin. It

is assumed that benzoic acid did not result in a deterioration of this rearing index, since at present publications on the subject present an advantageous effect of this acid on feed conversion ratio (FCR) [11, 12]. Only an addition of a mixture of capric and caprylic acids applied in the triglyceride form (0.3%) in group BMCT may have had a negative effect on FCR values. However, at present we lack information confirming this hypothesis. An increase in feed conversion ratio (FCR) was also recorded in the last two groups (BMCFA and MWMCFA). Both groups received an addition of a mixture of medium chain fatty acids (0.85%) at a 1:1:1 ratio. Their negative effect on feed intake and thus on body weight gains, resulting from the activation of the satiety center [14, 15], may have contributed to a deterioration of the index reflecting the utilisation of nutrients from feed (FCR). In the other groups (B, MW, MCT, BK1, BK2, BK3) no significant effect of feed additives was observed in relation to changes in feed conversion ratios in relation to PC and NC.

Based on the results of the conducted experiments it needs to be stated that the addition of salinomycin as well as the other feed additives did not result in an improvement of rearing indexes in broiler chickens in comparison to the group with no feed additives applied (NC). In view of the above it may be assumed that under good environmental conditions the diets for broiler chickens should not be enriched with mixtures of certain organic acids, particularly medium chain fatty acids (MCFA) with an addition of benzoic acid or calcium butyrate, since these compounds may potentially have a negative effect on body weight gains of chickens and their feed conversion ratios (FCR).

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