The effect of fumaric acid, dipromonium and vitamin C on the productivity of sows

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Abstract. The article presents the results of the effect of fumaric acid, dipromonium and vitamin C on productivity, physiological state and natural resistance of sows. The scientific and economic experience was carried out at the pig-breeding complex with a production capacity of 27 thousand heads “Voskhod” in the Mogilev region of Belarus. Forty primiparous gilts were divided into four groups (n = 10): a control and three experimental groups. Experimental gilts received basal diet supplemented with fumaric acid (4.0 g/kg of dry matter), dipromonium (0.4 g/kg) or vitamin C (0.1 g/kg) from 1 to 20 d of lactation. The animals of the control group did not receive the indicated preparation. The use of additives contributed to an increase in the milk yield of pigs, the viability of piglets and their growth rate by 21.1-30.0% (P<0.05), 6.0-6.6 and 10.0-27.9%, respectively, as well as influenced the morphological, biochemical and immunological parameters of the blood of pigs and their progeny.

1. Introduction
Present pig industrializing production methods contradict the evolved physiological particularities of the animals [1]. Pigs are more subjected to their organs and systems overstrain, to different immune and metabolic disorders due to the unbalanced feeding, stock concentration and space disproportions [2]. All these facts resulted in animal productivity decrease and their premature reject going up to 60%
of the sows. Therefore, the pig production efficiency is greatly depended on the replacement gilts productivity. So the immune system maintenance is one of the best ways for its improvement. It's a common thought that general resistance in animals might be stimulated by their maintenance improvement and by selection of the more resistant animals [3]. Feed is the main link of the animals with the nature [4]. Therefore, their body resistance is greatly relied on the complete feeds providing and on the right vitamins and minerals balance in the ration.

Fumaric acid, dipromonium and vitamin C are effective preventives of the stress negative effects in industrial pig production. Fumaric acid is an essential part of the cycle of tricarboxylic acids which produce one half of its energy [5, 6]. Energy production pathway of fumaric acid is shorter when compared to that of glucose and that's why it can be used for the urgent synthesis of ATP in stress [7]. Due to the overstrain of some organs and body systems, some 50-70% of pigs being bred on the industrial units have clinical disorders of liver. As a rule, the deficiency of vitamins in pigs under this technology of rearing is a result of liver morphological and functional disorders [8]. Dipromonium was proved to be effective in increasing its protective function, (dizopropylammonia dichloracetate) is a synthetic preparation which is used in medicare and veterinary practice to increase the body resistance to the negative effect of exogenous and endogenous toxins; it also has a lipotropic effect and normalizes the liver function.  

The milkability of a sow is determined by litter size and growth rate of their piglets during the suckling period. The main food for the suckling piglets is their mother's milk so the decrease of its quality directly affects the piglets productivity. The first days of life and the age of 20 days are critical for the piglets especially for those which were born and nursing by the gilts as they are exposed to stresses on industrial farms to an even greater extent than sows. As a result, functional disorders of their intericals and liver in particular are observed which may result in intoxication of their nursing piglets.

Our aim was to study if it was possible to increase the productive performance of suckling piglets by feeding fumaric acid, dipromonium and vitamin C in different combinations to their mothers and to estimate the influence of these biologically active substances on the physiological state, morphological, biochemical and immunological blood parameters of primiparous gilts and their progeny.

2. Material and methods

This trial was conducted on a farrow to finish unit (“Voskhod”) located in the Moguiley region of Belarus. The productive capacity was 27,000 heads. Forty primiparous sows that had their litter-size equalized to 10 to 11 piglets were distributed into 4 groups (10 animals each). In the control group they received the basic ration (BR), in Group 1 4 g of fumaric acid and 0.1 g of vitamin C complex was added (FA + C), in Group 2 0.4 g of dipromonium and 0.1 g of vitamin C complex (D + C) and in Group 3 4 g of fumaric acid and 0.4 g of dipromonium complex (FA + D) per 1 kg of dry matter, each. The experimental design is shown in table 1.

| Group          | Number of sows, heads | Feeding features       | Drug dose, g/kg of dry matter |
|----------------|-----------------------|------------------------|-----------------------------|
| Control        | 10                    | Basis ration (BR)      | -                           |
| 1 experimental | 10                    | BR + of fumaric acid + of vitamin C (FA + C) | 4 + 0.1                     |
| 2 experimental | 10                    | BR + of dipromonium + of vitamin C (D + C)  | 0.4 + 0.1                   |
| 3 experimental | 10                    | BR + of fumaric acid + of dipromonium (FA + D) | 4 + 0.4                     |

Table 1. Scientific and economic experiment design.
The treatment diets were fed during the first 20 d of the lactation, afterward the basal diet was fed to all sows. The diets were fed in a dry all-mash form. Composition of the basal control diet is shown in table 2.

Table 2. Composition of lactation control diet fed to sowsa.

| Ingredients       | %    |
|-------------------|------|
| Corn              | 48.1 |
| Barley            | 15.0 |
| Wheat             | 10.0 |
| Soybean meal      | 14.8 |
| Fish meal         | 2.0  |
| Fodder yeast      | 2.0  |
| Grass meal        | 5.0  |
| Salt              | 0.4  |
| Phosphate         | 0.7  |
| Limestone         | 1.0  |
| Premixb,c         | 1.0  |

aThe diet was formulated to contain on a dry matter (DM) basis (per kg diet): 145 g digestible protein, 8 g lysine.

bThe premix supplies (per kg DM): 16 mg of Fe, 17 mg of Cu, 87 mg of Zn, 1.7 mg of Co and 0.35 mg of I.

cThe premix supplies (per kg DM): 5.8 IU of vitamin A, 0.6 IU of vitamin D3, 41 mg of vitamin E, 2.7 mg of thiamine, 7 mg of B3, 23 mg of B6, 1160 mg of B12, 29 mcg vitamin B15 and 3.5 mg of vitamin C.

Blood samples were taken from sows before pigs were weaned on the 30th to 32nd days of lactation and from the piglets at 70 d of age. Pigs were weaned at 35 d of age. Blood were taken from the ear vein of five animals in each treatment group before the morning feeding.

The following morphological and biochemical indices were determined: erythrocytes and hemoglobin content by photoelectric colorimeter KFK-2; leucocytes content by the microparticles counter Picoscale-PS-4 (HUNGARY); and protein, cholesterol, triglycerides, glucose, BUN, creatinine, total and direct bilirubin, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), lactate dehydrogenase (LD), γ-glutamyltransferase (γ-GT), creatine kinase (CK), amylase, Ca and inorganic P contents using a biochemical autoanalyser (BECKMAN, SYNCHRON CX-4, USA). Protein fractions were determined by agar-gel electrophoresis and Cu, Fe, Co, Mn, Zn were determined using an atom absorption spectrophotometer (Perkin Elmer-5000, Sweden).

Body resistance was determined by the humoral resistance rates according to: serum bactericidal activity (SBA) using the photoephelometric method in relation to the colon bacillus daily growth; serum lisocyme activity (SLA) using the nephelometric method in relation to the test growth (Micr. lysodeicticus); titre of the normal agglutinins using the tube method with the colon bacillus daily growth as an antigen; and immunoglobulins (class G and M) using commercial monospecific antiseraums and the immunochemical system ICS-II equipment, (BECKMAN, USA).

The obtained data was statistically analyzed using SPSS- software (version 25.0), and the data were expressed as mean ± standard deviations (SD) and it statistically analyzed by one-way ANOVA (Analysis of Variance) for multiple comparisons. P values less than 0.05 were considered significant.

3. Results and discussion

Feeding primiparous sows diets supplemented by the biologically activic substances during the first 20 days of lactation resulted in higher productivity of piglets (table 3). For tables 3-6 probability was estimated in the comparison of each treatment with the control. Treatments were fed during the first 20 days of lactation. Sow measurements were made on day 21. Ten sows per treatment mean ± SEM. Measurements were taken on day 70 – pigs weaned on day 35.
When supplementing the diet with fumaric acid and vitamin C (Group 2) or dipromonium and vitamin C (Group 3) the milking ability of the sows was increased by 21.1…30.0% (P<0.05…0.01). Percentage of pigs reared to 21 d was only numerically increased for all treatment groups compared with controls. Also, the growth rate of piglets after weaning was better than that of controls by 4.0-32.0 and 3.0-36.0% at the age of 70 days and during the period from 21 to 70 days of life, respectively.

**Table 3.** Effect of dietary additions of fumaric acid (FA), vitamin C (C) and dipromonium (D) during lactation on sow productivity and postweaning performance of pigs.

| Measurements | Control | 1 Group | 2 Group | 3 Group |
|--------------|---------|---------|---------|---------|
| Sows         |         |         |         |         |
| Milkability, kg | 44.0±1.7 | 53.3±3.1* | 57.2±2.7** | 48.5±3.8 |
| Pigs reared, %  | 90.6±2.9 | 96.0±2.4 | 96.4±2.2 | 96.6±2.1 |
| Avg pig BW, kg  | 4.68±0.17 | 5.43±0.19* | 5.63±0.34* | 5.02±0.39 |
| ADG, g        | 161±8 | 196±9 | 206±16 | 177±19 |
| Pigs          |         |         |         |         |
| Postweaning survival, % | 100 | 100 | 100 | 100 |
| Avg BW, kg    | 17.1±1.4 | 5.5±0.20 | 5.9±0.18 | 5.9±0.19 |
| ADG, g        | 249±13 | 319±14 | 339±21 | 256±30 |

* P<0.05; ** P<0.01

However, these supplements did not affect the days to estrus after weaning, but they influenced the biochemical processes in gilts' body what was evidenced by the results of blood morphological, biochemical and immunological analyses (tables 4 and 5).

**Table 4.** Blood morphological and serum biochemical indices of sows as influenced by dietary additions of fumaric acid, vitamin C and dipromonium during lactation.

| Indices                    | Control | 1 Group | 2 Group | 3 Group |
|---------------------------|---------|---------|---------|---------|
| Red blood cells, 10^12/L  | 5.33±0.09 | 5.08±0.09 | 5.17±0.10 | 5.92±0.24 |
| Hemoglobin, g/L           | 120.7±1.46 | 114.2±1.36* | 134.0±2.50* | 145.0±2.90** |
| White blood cells, 10^9/L | 11.6±0.09 | 10.0±0.1 | 2.46±0.13 | 2.69±0.12 |
| Holesterol, mmol/L        | 2.76±0.07 | 2.65±0.08 | 2.46±0.13 | 2.69±0.15 |
| Triglycerides, mmol/L     | 0.45±0.005 | 0.49±0.10* | 0.40±0.004* | 0.41±0.017+ |
| Glucose, mmol/L           | 4.51±0.21 | 6.12±0.14** | 4.77±0.09 | 5.12±0.35 |
| Protein, g/L              | 77.4±0.51 | 73.4±1.12* | 73.7±0.19** | 75.0±0.70* |
| Albumins, %               | 41.5±0.2 | 40.1±0.1** | 40.0±0.2** | 40.9±0.1* |
| Globulins, %              | 58.6±0.2 | 59.9±0.1** | 60.0±0.2** | 59.1±0.1* |
| α-globulins, %            | 12.9±0.1 | 12.4±0.1* | 12.0±0.3* | 11.9±0.1** |
| β-globulins, %            | 12.5±0.1 | 12.9±0.1 | 13.0±0.1* | 12.6±0.1 |
| γ-globulins, %            | 33.1±1.2 | 34.6±0.1 | 35.0±0.4 | 34.5±0.2 |
| BUN, mmol/L               | 6.97±0.06 | 8.19±0.39 | 7.11±0.48 | 6.60±0.03 |
| Creatinine, umol/L        | 145.2±0.37 | 167.5±10.7 | 145.0±7.1 | 146.0±1.3 |
| Bilirubin total, umol/L   | 6.0±0.2 | 7.4±1.95 | 3.4±1.0+ | 5.3±0.1* |
| Bilirubin direct, umol/L  | 0.0 | 0.0 | 0.0 | 0.0 |

* P<0.05; ** P<0.01
Table 5. Blood morphological and serum biochemical indices of pigs as influenced by dietary additions of fumaric acid, vitamin C and dipromonium during lactation.

| Indices                        | Control    | 1 Group   | 2 Group   | 3 Group   |
|--------------------------------|------------|-----------|-----------|-----------|
| Red blood cells, 10¹²/L        | 5.56±0.14  | 5.10±0.10 | 5.04±0.09 | 4.94±0.01*|
| Hemoglobin, g/L                | 102.4±4.5  | 90.7±2.0  | 87.4±0.7  | 87.3±0.7  |
| White blood cells, 10⁹/L       | 10.8±0.5   | 10.3±0.9  | 7.30±0.4  | 7.50±0.7**|
| Holesterin, mmol/L             | 2.52±0.16  | 2.41±0.06 | 2.42±0.10 | 2.26±0.10 |
| Triglycerides, mmol/L          | 1.08±0.12  | 0.98±0.03 | 1.05±0.07 | 0.73±0.09*|
| Glucose, mmol/L                | 5.56±0.34  | 7.01±0.30*| 7.96±0.80*| 6.66±0.11*|
| Protein, g/L                   | 67.2±2.6   | 60.3±2.9  | 58.3±4.9  | 60.5±2.1  |
| Albumins, %                    | 42.0±0.2   | 42.7±0.4  | 43.4±0.3  | 41.6±0.3  |
| Globulins, %                   | 58.0±0.2   | 56.3±0.4  | 56.6±0.3  | 58.4±0.3  |
| α-globulins, %                 | 15.0±0.3   | 13.5±0.2  | 14.3±0.3  | 14.7±0.4  |
| β-globulins, %                 | 15.0±0.3   | 15.2±0.1  | 15.1±0.1  | 16.1±0.5  |
| γ-globulins, %                 | 27.4±0.2   | 27.6±0.5  | 27.1±0.5  | 27.6±0.6  |
| BUN, mmol/L                    | 5.96±0.23  | 5.47±0.24 | 6.14±0.66 | 5.04±0.38 |
| Creatinine, umol/L             | 107.0±2.2  | 107.7±3.6 | 97.4±1.5  | 107.0±1.0 |
| Bilirubin total, umol/L        | 12.3±2.2   | 10.5±1.1  | 13.9±2.6  | 15.7±2.8  |
| Bilirubin direct, umol/L       | 4.6±1.1    | 4.3±0.4   | 4.9±0.7   | 7.9±2.2   |

* P<0.05; ** P<0.01

The analysis of enzymes concentration in blood serum of experimental sows before piglets weaning showed a higher activity of AST and ALT (P<0.05 - 0.001) (table 7). The activity of LD, ALP and KK having been higher (P<0.1 - 0.05) in sows of Group3 (fumaric acid and vitamin C). As for the activity of ALP and -GT, it was lower in blood serum of animals which were fed dipromonium and vitamin C (P<0.05). The amilase concentration was lower in gilts on diets supplemented with dipromonium (P<0.01).

Table 6. Serum enzymes of sows and pigs as influenced by dietary additions of fumaric acid, vitamin C and dipromonium during lactation.

| Indices          | Control | 1 Group | 2 Group | 3 Group |
|------------------|---------|---------|---------|---------|
| **Sows**         |         |         |         |         |
| ALT, IU/L        | 32.7±0.2 | 42.0±3.3* | 39.4±0.9** | 36.0±1.9 |
| AST, IU/L        | 34.0±0.7 | 49.6±0.8*** | 44.7±2.7* | 41.2±2.6* |
| LD, IU/L         | 245.4±4.3 | 290.2±12.1* | 253.0±13.7 | 251.0±0.7 |
| ALP, IU/L        | 58.8±2.5 | 95.4±16.6** | 46.5±3.8* | 56.6±4.7  |
| γ–GT, IU/L       | 66.6±10.0 | 60.6±2.9 | 34.7±0.4* | 45.0±6.6  |
| CK, IU/L         | 172.9±2.9 | 187.2±3.6* | 174.0±12.7 | 175.0±11.6 |
| Amylase, IU/L    | 1437±3.3 | 1392±32.0 | 1153±31.8** | 1113±6.4*** |
| **Pigs**         |         |         |         |         |
| ALT, IU/L        | 31.4±3.0 | 24.7±2.4 | 25.7±2.2 | 27.4±0.8  |
| AST, IU/L        | 29.2±3.0 | 37.2±2.7 | 35.4±1.6 | 47.4±3.9* |
| LD, IU/L         | 989±93   | 221±0.7** | 332±27** | 392±37   |
| ALP, IU/L        | 94±6.1   | 126±3.2** | 111±4.0* | 139±6.3** |
| γ–GT, IU/L       | 33.0±3.3 | 26.2±2.3 | 20.5±1.6 | 37.5±7.8  |
| CK, IU/L         | 909±355  | 534±176  | 546±82  | 657±97   |
| Amylase, IU/L    | 1266±44  | 1329±17  | 1263±13  | 1275±12  |

* P<0.05; ** P<0.01.
Table 7. Serum mineral of sows and pigs as influenced by dietary additions of fumaric acid, vitamin C and dipromonium during lactation.

| Indices    | Control       | 1 Group       | 2 Group       | 3 Group       |
|------------|---------------|---------------|---------------|---------------|
| Sows       |               |               |               |               |
| Ca, mmol/L | 2.50±0.03     | 2.41±0.04     | 2.49±0.01     | 2.44±0.04     |
| P, mmol/L  | 2.70±0.01     | 2.65±0.07     | 2.13±0.01***  | 2.10±0.09***  |
| Cu, umol/L | 4.30±0.47     | 2.61±0.04     | 2.98±0.11*    | 3.04±0.12    |
| Fe, mmol/L | 5.61±0.05     | 5.33±0.06*    | 5.43±0.05*    | 5.82±0.13    |
| Co, umol/L | 0.42±0.03     | 0.23±0.03*    | 0.22±0.03**   | 0.20±0.03*   |
| Mn, umol/L | 0.49±0.04     | 0.25±0.04**   | 0.31±0.03*    | 0.49±0.04    |
| Zn, umol/L | 6.33±0.16     | 4.89±0.15**   | 5.08±0.31*    | 5.36±0.14    |
| Pigs       |               |               |               |               |
| Ca, mmol/L | 3.18±0.07     | 2.98±0.07     | 3.09±0.18     | 2.98±0.14    |
| P, mmol/L  | 3.76±0.15     | 3.66±0.05     | 3.85±0.07     | 3.92±0.05    |
| Cu, umol/L | 3.35±0.15     | 3.39±0.09     | 3.76±0.16     | 4.24±0.06**  |
| Fe, mmol/L | 6.05±0.14     | 5.21±0.25*    | 5.44±0.05*    | 4.85±0.19**  |
| Co, umol/L | 0.17±0.03     | 0.34±0.03     | 0.51±0.01***  | 0.46±0.03**  |
| Mn, umol/L | 2.47±0.03     | 2.87±0.07**   | 3.17±0.13***  | 3.49±0.07*** |
| Zn, umol/L | 4.59±0.16     | 4.43±0.46     | 4.63±0.11     | 3.70±0.13    |

* P<0.05; ** P<0.01.

All the experimental sows had lower concentration of trace elements and nonorganic P when compared to control animals, especially in groups receiving vitamin C and fumaric acid (Group 1), vitamin C and dipromonium (Group 2) (P<0.05 - 0.001). It may be explained by the greater transfer of these substances into the milk of experimental sows (table 8).

Table 8. Humoral resistance factors of sows and pigs as influenced by fumaric acid, vitamin C and dipromonium additions during lactation.

| Indices                  | Control       | 1 Group       | 2 Group       | 3 Group       |
|--------------------------|---------------|---------------|---------------|---------------|
| Sows                     |               |               |               |               |
| Serum active, %          |               |               |               |               |
| Bactericidal             | 14.4±0.61     | 16.4±0.44*    | 16.0±0.62     | 16.9±1.88     |
| Lisocymal                | 2.26±0.38     | 7.17±0.99**   | 5.87±0.73*    | 3.87±0.23*    |
| Normal agglutinins, titer| 1:14±2.4      | 1:14±2.4      | 1:10±0.1      | 1:14±2.4      |
| Immunoglobulins          |               |               |               |               |
| Class G, mg/dL           | 504±4.39      | 462±21.0      | 418±1.07***   | 468±14.7      |
| Class M, mg/dL           | 102±6.1       | 63±3.3**      | 98±10.7       | 100±0.95      |
| Pigs                     |               |               |               |               |
| Serum active, %          |               |               |               |               |
| Bactericidal             | 19.5±0.69     | 20.9±0.72     | 22.8±0.54*    | 22.2±0.47*    |
| Lisocymal                | 22.3±0.55     | 20.4±0.48     | 21.5±0.46     | 21.2±0.92*    |
| Normal agglutinins, titer| 1:5±1.1       | 1:5±1.1       | 1:7±1.2       | 1:8±1.2       |
| Immunoglobulins          |               |               |               |               |
| Class G, mg/dL           | 388±7.20      | 261±35.70     | 205±26.00**   | 218±48.70*    |
| Class M, mg/dL           | 79±10.3       | 77±3.96       | 55±2.40*      | 56±3.99       |

* P<0.05; ** P<0.01.

When estimating the natural resistance of experimental animals it was established that they had the higher level of SBA and SLA than control ones (P<0.2-0.01). It would be suggested that the lactation did affect their humoral factors of body protection on less extent when compared to control animals (table 8).
A lower level of IgG was observed in experimental groups (P<0.2-0.01). As this kind of IgG was more active in reactions of neutralization, then its low level may be explained by the fact that the biochemical processes inhibited the production of toxins and promoted their rapid removing from the body.

Thus, vitamin and other active substances fed to the primiparous gilts during the first 20 days of lactation resulted in correction of the biochemical processes in their body. It would be suggested that biologically active substances fed to the sows helped their piglets to overcome easier the most critical period in their life and to gain more than their control contemporaries (table 3). As for the suckling piglets, their biochemical patterns were conserved after weaning (tables 4-8).

The level of leucocytes in the blood of experimental piglets was lower (P<0.01) and the level of glucose was higher (P<0.05) than that of control ones, the level of glucose being higher in serum blood of those piglets which had higher productivity (Group 1 and 2) (tables 4-7). The content of crude protein in experimental sows receiving vitamin C (Group 1 and 2), and in their piglets was lower too (P<0.2) due to the decrease of globulin level (P<0.05) and especially of its α-fraction (P<0.05-0.01), while the percent of albumins was higher (P<0.05). A higher, activity of AST (P<0.2 to 0.05) and ALP (P<0.1 to 0.01) was characteristic to the piglets from experimental groups but at the same time, they had a lower level of LD (P<0.01). It would be suggested that their biochemical patterns were similar to those of the adult pigs, i.e. they had adapted to new conditions of their life after weaning. It was also confirmed by a lower concentration of CK. Besides, the piglets of sows from group 1 (vitamin C and fumaric acid) and group 2 (vitamin C and dipromonium) had lower level of γ-GT (P<0.2 to 0.05).

As γ-GT is a part of monooxygenase system which is to maintain the chemical homeostasis, and KK and LD indicate stresses conditions in animals it can be suggested that the response of experimental piglets to the negative effects of environment influenced the biochemical processes in the body on less extent than in controls [10]. Regarding the mineral composition of blood, a lower concentration of Fe (P<0.05-0.01) and higher concentration of Mn (P<0.01-0.001) was established in all experimental animals. The piglets from sows of Group 2 and 3 (dipromonium) had a higher level of Cu (P<0.2-0.01) and Co (P<0.01) in the blood. As for the humoral factors of body resistance, the piglets of the 1rd and 2th groups had the higher level of serum bactericidal activity (P<0.05), but at the same time, they had a lower level of IgG (P<0.2-0.01).

These trials were repeated twice in different seasons and the results of the productivity, morphological, biochemical and immunological composition of blood were similar.

4. Conclusion

In the course of scientific research, it was found that the use of gilts in experimental groups with the main diet – fumaric acid (4.0 g/kg of dry matter), dipromonium (0.4 g/kg) or vitamin C (0.1 g kg) from 1 to 20 days of lactation, contributed to an increase in the milk production of pigs, the viability of piglets and their growth rate by 21.1-30.0 % (P<0.05), 6.0-6.6 and 10.0-27.9 % respectively.

The use of proven supplements with the main diet also influenced the morphological, biochemical and immunological parameters of the blood of pigs and their offspring.

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