

The Influence of Metabolic Products of *Echinococcus granulosus* on the Oxidation Processes in the Organism of Pigs

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Abstract

This article shows the effect of *Echinococcus granulosus* metabolic products on the oxidative processes in the organism of pigs. The research has shown that echinococci metabolism in tissues and organs of pigs results in formation and accumulation of aldehydes, ethers, alcohols and ketones, which results in deterioration in the quality of animals' slaughter products. In case of pigs' echinococcosis, the total concentration of carboxylic acids in all organs and tissues of pigs was 4 times lower, while, on the contrary, the total concentration of aldehydes was 9 times higher, of esters – 12 times higher than in clinically healthy animals. Based on the results of the research, it has been found that in case of high degree of pigs' infestation with echinococci, compared to clinically healthy animals, intermediate products of volatile organic compounds' decomposition were intensively forming, resulting in the deterioration of the quality of products of animal slaughter.

Keywords: echinococcosis, *echinococcus granulosus*, organs, pig breeding, quality, safety, slaughter products, tissues, volatile organic substances.

INTRODUCTION

Biological and food safety of products is currently urgent; it has now gone beyond purely economic issues and become one of the main modern social problems [1-5]. High quality of food products is determined by a set of indicators, of which the most important ones are quality and safety, and is considered as a set of properties of the components that completely eliminate their harmful effects on human health. By systematic monitoring, conformity of products' quality to specified requirements is ensured, and presence of harmful ingredients is detected [6-10].

One of the main tasks in food industry is assessing quality of food products, their safety, monitoring and analysis of component parts [11-13]. Changing quality and loss of nutritional value of food products are mainly due to oxidative processes that result in deterioration of the product [14-16]. At the initial stage of lipid oxidation, peroxides and hydroperoxides (primary products of lipid degradation) are formed, which have a toxic effect on the human organism, although they insignificantly affect functional, technological and organoleptic properties of the food product [17, 18]. With further oxidation, aldehydes and ketones (secondary products of lipids' decomposition) are formed, which give specific rancid taste to the product [19-22].

During vital activity of *Echinococcus granulosus* in the organisms of animals during oxidation of organic substances, formation and accumulation of intermediate products occurs [24-25].

MATERIALS AND METHODS

In this respect, concentration of intermediate products during organic substances' decomposition in the muscle tissue and internal organs has been determined in case of echinococcosis in pigs, which allowed to determine the influence of helminths' waste products on accumulation of volatile organic substances.

Volatile organic compounds were determined on a Crystal 2000 gas-liquid chromatograph. To determine volatile organic compounds in the organs and tissues of clinically healthy animals and in case of echinococcosis, a weighed 6 g sample was taken, and volatile organic compounds were distilled with water vapor, after which the obtained extract was collected into a 50 ml measuring flask. 2 µl of extracts from organs and tissues were taken for determining volatile substances – carboxylic acids, aldehydes, ketones, ethers and alcohols. The Crystal 2000-M gas-liquid chromatograph has a 50 mm long quartz capillary column with the internal diameter of 0.32 mm; liquid stationary phase is

FFAP; temperature of chromatograph injector is 170°C; the heating temperature of DIP detector is maintained at 170°C; the input pressure at the column is 60 kPa; the temperature of the columns' thermostat is 50°C, whereas the isotherm passes during 7 minutes. The process of programming the temperature occurs at the rate of 5 °C per minute up to 140 °C, exposure duration is 20 minutes at the rate of 10 °C per minute up to 160 °C and exposure until the end of analysis is at least 40 minutes; carrier gas flow rate through the column is 1.21 cm³/min; the vaporizer has flow division, the flow division ratio is 1:33; the carrier gas is nitrogen; hydrogen flow rate is 25 cm³/min; air flow rate is 250 cm³/min; the volume of the sample is 2 mm³; the analysis takes 60 minutes.

The method of absolute calibration was used for calculating the amount of volatile organic compounds in organs and tissues. The model blend of volatile organic compounds (carbon acids, aldehydes, ketones, ethers and alcohols) was prepared in 40% aqueous-alcohol solution that had been selected by the composition similar to the studied objects. To determine concentration of volatile organic substances in case of pigs' echinococcosis, an extract of organs and tissues (rib eye, cardiac muscle, liver, lungs, spleen and kidneys) was used. One average sample of organs and tissues was taken from 15 animals. Studied animals were divided into two groups, and 15 average samples were taken from each of them. The reference group included clinically healthy animals, the first experimental group included low degree of infestation with echinococci, and the second experimental group included high degree of infestation with echinococci.

RESULTS AND DISCUSSION

The research has shown that in case of low degree of pigs' infestation with echinococci, concentration of acetic acid in the rib eye was lower by 80 % (5.1 times), propionic acid – by 90 % (33 times) than in clinically healthy animals. The total concentration of carboxylic acids in the rib eye was 14.27 mg/kg, and was 5 times lower than in clinically healthy pigs. In the cardiac muscle extract, concentration of acetic acid was 8 times lower, of propionic acid – 1.3 times lower, and, on the contrary, the content of butyric acid was 7 times higher, isobutyric acid - 3 times higher, isovaleric acid - 2 times higher than in clinically healthy animals. The total concentration of carboxylic acids in the cardiac muscle extract was 9.71 mg/kg, and was 6 times lower than in clinically healthy pigs (Table 1).

Table 1. Concentration of volatile organic substances in the rib eye extract in case of pigs' echinococcosis (M±m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	67.35±0.73	13.18±0.13***	7.18±0.14***
Propionic	2.96±0.17	0.29±0.01***	0.09±0.01***
Isobutyric	0.00±0.00	0.33±0.01	0.43±0.01
Butyric	0.00±0.00	0.23±0.01	0.12±0.01
Isovaleric	0.25±0.01	0.24±0.02	4.10±0.12
Methanol	1.43±0.01	2.84±0.04***	10.23±0.14***
Ethanol vol. %	0.00±0.00	0.00±0.00	0.02±0.01
Phenylethanol	0.00±0.00	1.80±0.01	0.37±0.01
1-propanol	0.00±0.00	0.00±0.00	1.36±0.01
Isoamyl	0.29±0.01	0.38±0.02***	3.45±0.15***
Isobutanol	0.00±0.00	0.19±0.01	0.39±0.01
1-amylol	0.00±0.00	0.00±0.00	2.89±0.15
1-hexanol	0.00±0.00	0.22±0.01	0.00±0.00
2,3-buteneglycol	2.88±0.03	6.96±0.15***	3.87±0.11***
1,3-propylene glycol	0.00±0.00	0.00±0.00	9.05±0.17
Acetaldehyde	1.93±0.06	3.00±0.13***	7.16±0.16***
Furfural	0.89±0.02	14.55±0.24***	33.84±0.54***
Acetoin	8.28±0.19	9.99±0.14	11.73±0.27***
Capric aldehyde	0.00±0.00	2.71±0.11	1.35±0.01
Isoamyl acetate	0.00±0.00	0.00±0.00	0.27±0.01
Methyl caprylate	0.22±0.01	0.35±0.02***	3.85±0.13***
Methyl acetate	0.00±0.00	0.00±0.00	2.76±0.15
Ethyl acetate	0.00±0.00	0.26±0.01	0.66±0.03
Ethyl formiate	0.27±0.01	1.32±0.03***	2.04±0.15***
Diacetyl	0.68±0.03	1.43±0.02***	4.15±0.15***

***P>0.001

Table 2. Concentration of volatile organic substances in the extract of pigs' cardiac muscle in case of echinococcosis (M±m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	55.61±0.77	6.98±0.16***	6.87±0.17***
Propionic	1.18±0.01	0.89±0.01***	0.10±0.01***
Isobutyric	0.07±0.01	0.18±0.01***	1.70±0.01***
Butyric	0.18±0.01	1.20±0.01***	3.20±0.15***
Valeric	0.00±0.00	0.00±0.00	1.99±0.02
Isovaleric	0.22±0.01	0.46±0.01***	1.34±0.04***
Methanol	0.49±0.01	1.10±0.01***	7.62±0.20***
Ethanol vol. %	0.00±0.00	0.00±0.00	0.03±0.01
Phenylethanol	0.00±0.00	0.39±0.01	0.59±0.02
Isoamyl	0.19±0.01	0.30±0.01***	2.29±0.04***
1-amylol	0.00±0.00	0.00±0.00	1.08±0.01
2-butanol	0.00±0.00	0.00±0.00	0.51±0.01
2,3-buteneglycol	0.63±0.01	0.00±0.00	6.46±0.15
1,3-propylene glycol	0.00±0.00	0.00±0.00	0.53±0.01
Acetaldehyde	4.24±0.04	15.48±0.26***	22.41±0.62***
Furfural	1.33±0.05	9.06±0.14***	13.66±0.39***
Acetoin	8.10±0.08	17.94±0.18***	22.45±0.22***
Capric aldehyde	0.00±0.00	1.44±0.01	1.50±0.04
Methyl acetate	0.00±0.00	0.62±0.01	1.58±0.05
Ethyl variate	1.31±0.01	0.00±0.00	0.00±0.00
Ethyl formiate	1.70±0.03	2.24±0.02***	3.77±0.15***
Diacetyl	0.90±0.01	1.19±0.01***	2.06±0.05***

***P>0.001

In the cardiac muscle extract, concentration of acetic acid was 8 times lower, of propionic acid – 1.3 times lower, and, on the contrary, the content of butyric acid was 7 times higher, isobutyric acid - 3 times higher, isovaleric acid - 2 times higher than in clinically healthy animals. The total concentration of

carboxylic acids in the cardiac muscle extract was 9.71 mg/kg, and was 6 times lower than in clinically healthy pigs (Table 2).

In the tissues of liver, in case of low degree of pigs' infestation with echinococci, concentration of acetic and isovaleric acid was 5 times lower, propionic acid – 12 times

lower, isovaleric acid – 2 times lower than in clinically healthy animals. In liver tissues, the total concentration of carboxylic acids reached 16.78 mg/kg, and was 4 times lower than in clinically healthy pigs. In the lung tissues, concentration of acetic acid was 5 times lower, propionic acid – 16 times lower than in clinically healthy animals (Table 3).

In the lung tissues, the total concentration of carboxylic acids reached 16.03 mg/kg, and was 5 times lower than in clinically healthy animals. In the spleen tissues, concentration of acetic acid was 13 times lower, propionic acid – 7 times lower, isovaleric acid - 2 times lower than in clinically healthy animals (Table 4).

Table 3. Concentration of volatile organic substances in the extract of pigs' liver in case of echinococcosis (M±m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	62.60±1.02	12.38±0.22***	6.99±0.13***
Propionic	2.80±0.11	0.24±0.01***	0.86±0.01***
Isobutyric	0.00±0.00	0.77±0.01	3.71±0.10
Butyric	0.00±0.00	1.98±0.10	3.14±0.17
Valeric	0.00±0.00	0.24±0.01	1.56±0.02
Isovaleric	0.18±0.01	0.39±0.01***	1.58±0.06***
Capric	0.00±0.00	0.78±0.01	1.73±0.06
Methanol	0.57±0.01	2.06±0.02***	29.44±0.29***
Phenylethanol	0.00±0.00	5.64±0.04	3.78±0.11
Isoamyl	0.00±0.00	0.53±0.01	1.72±0.05
Isobutanol	0.00±0.00	0.99±0.03	1.46±0.01
1-amylol	0.00±0.00	2.50±0.04	5.09±0.16
2-butanol	0.00±0.00	1.62±0.05	2.91±0.09
1-hexanol	0.00±0.00	0.49±0.01	1.24±0.02
2,3-butylene glycol	0.00±0.00	18.16±0.20	0.00±0.00
1,3-propylene glycol	0.60±0.01	4.09±0.15***	7.05±0.16***
Acetaldehyde	0.65±0.01	5.90±0.13***	8.48±0.17***
Furfural	0.69±0.01	1.59±0.02***	12.80±0.35***
Acetoin	7.91±0.14	9.46±0.16***	10.72±0.09***
Capric aldehyde	0.00±0.00	1.55±0.04	22.39±0.30
Isoamyl acetate	0.00±0.00	0.00±0.00	1.30±0.01
Methyl caprylate	0.00±0.00	2.41±0.04	7.00±0.15
Ethyl acetate	0.00±0.00	0.98±0.07	3.26±0.07
Ethyl variate	0.39±0.01	0.00±0.00	0.00±0.00
Ethyl formiate	0.17±0.01	2.77±0.06***	4.10±0.12***
Diacetyl	0.23±0.01	0.43±0.01***	3.31±0.08***

***P>0.001

Table 4. Concentration of volatile organic substances in the extract of lung tissues in case of echinococcosis (M±m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	73.99±0.78	14.49±0.18***	5.05±0.15***
Propionic	12.36±0.41	0.77±0.02***	0.16±0.01***
Isobutyric	0.00±0.00	0.40±0.01	0.31±0.01
Isovaleric	0.00±0.00	0.37±0.01	2.81±0.06
Methanol	1.66±0.01	3.03±0.14***	20.87±0.37***
Phenylethanol	0.00±0.00	0.29±0.01	0.43±0.01
1-propanol	0.00±0.00	0.00±0.00	0.18±0.01
Isoamyl	0.19±0.01	0.28±0.01***	3.04±0.13***
1-hexanol	0.00±0.00	0.00±0.00	0.65±0.02
2,3-butylene glycol	0.00±0.00	0.00±0.00	2.41±0.05
1,3-propylene glycol	0.00±0.00	3.00±0.18	6.05±0.16
Acetaldehyde	3.39±0.08	4.10±0.13***	11.08±0.35***
Furfural	0.88±0.01	4.04±0.16***	19.47±0.39***
Acetoin	0.00±0.00	3.45±0.06	5.88±0.18
Capric aldehyde	0.00±0.00	15.34±0.21	31.84±0.31
Methyl caprylate	0.00±0.00	0.37±0.02	0.56±0.01
Ethyl acetate	0.00±0.00	0.19±0.01	0.51±0.01
Ethyl formiate	0.21±0.01	1.81±0.03***	3.12±0.16***
Ethyl caprylate	0.00±0.00	0.22±0.01	0.50±0.01
Diacetyl	0.26±0.01	0.35±0.01***	3.13±0.11***

***P>0.001

The total concentration of carboxylic acids in spleen tissues was 7.12 mg/kg and was 2 times lower than in clinically healthy pigs. In the renal tissue of pigs, concentration of acetic and propionic acids was 2 times lower than in clinically healthy animals. The total concentration of carboxylic acids in the renal tissues was 74.46 mg/kg, and was 2 times lower than in clinically healthy pigs.

With the low level of pigs' infestation with echinococci, in the rib eye extract, concentration of acetaldehyde was 2 times higher, furfural – 16 times higher, acetone – 1.2 times higher than in clinically healthy animals. The total concentration of aldehydes was 30.25 mg/kg, and was 3 times higher than in clinically healthy pigs. In the extract of the cardiac muscle, concentration of furfural was 7 times higher, acetaldehyde – 4 times higher, acetoin – 2 times higher than in clinically healthy animals. The total concentration of aldehydes was 43.92 mg/kg, and was 3 times higher than in clinically healthy pigs; concentration of capric aldehyde – 1.6 times higher.

In the extract of the liver of pigs with low degree of infestation with echinococci, concentration of acetaldehyde was 9 times higher, furfural – 2 times higher, acetone – 1.2 times higher than in clinically healthy animals. The total concentration of aldehydes was 18.50 mg/kg, and was 2 times higher than in clinically healthy pigs. In the lung tissue, concentration of furfural was 5 times higher, acetaldehyde - 1.2 times higher than in clinically healthy animals. The total concentration of aldehydes was 26.93 mg/kg, and was 6 times higher than in clinically healthy pigs.

With the low degree of pigs' infestation with echinococci, concentration of furfural in the spleen extract was 22 times higher, acetaldehyde - 5 times higher, capric aldehyde and acetone – 3 times higher; the total concentration of aldehydes reached 40.70 mg/kg, and was 7 times higher than in clinically healthy pigs. In the kidneys' extract, concentration of acetaldehyde was 3 times higher, capric aldehyde and acetone – 2

times higher; the total concentration of aldehydes reached 41.32 mg/kg, and was 10 times higher than in clinically healthy pigs (Table 5).

The maximum concentration of aldehydes in case of a low level of pigs' infestation with Echinococci was noted in the extract of the heart muscle, which was 2 times higher than in the extract of rib eye, liver, and lungs, and 1.1 times higher than in the spleen and kidneys' extract.

With the low degree of pigs' infestation with echinococci, in the rib eye extract complex ethers were identified: concentration of methyl caprylate was 2 times higher, of ethylformate – 5 times higher, the total concentration of esters was 1.93 mg/kg, and was 4 times higher than in clinically healthy pigs. In cardiac muscle, esters were identified: concentration of ethyl formiate was 1.3 times higher; the total concentration of esters in the cardiac muscle was 2.86 mg/kg, and was 1.1 times higher than in clinically healthy pigs. In the liver tissues, esters were identified: concentration of ethyl formiate was 16 times higher; the total concentration of esters in the liver was 6.16 mg/kg, and was 11 times higher than in clinically healthy pigs.

In the lung tissue with low degree of pigs infestation with echinococci esters were identified: concentration of ethyl formiate was 9 times higher; the total concentration of esters reached 2.59 mg/kg, and was almost 12 times higher than in clinically healthy pigs. In the spleen tissues, esters were identified: concentration of methyl caprylate was 19 times higher, ethyl formiate - 5 times higher; the total concentration of esters in spleen extract was 11.37 mg/kg, and was 29 times higher than in clinically healthy pigs. In the kidney tissue extract with low degree of pigs' infestation with echinococci, esters were identified: concentration of methyl caprylate reached 1.67 ± 0.01 mg/kg, ethyl acetate – 0.57 ± 0.02 mg/kg, and ethyl formiate – 3.21 ± 0.14 mg/kg. The total concentration of esters reached 5.45 mg/kg.

Table 5. Concentration of volatile organic substances in the extract of pigs' spleen in case of echinococcosis (M \pm m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	82.16 \pm 0.37	6.23 \pm 0.08***	7.06 \pm 0.18***
Propionic	4.17 \pm 0.18	0.59 \pm 0.01***	0.92 \pm 0.01***
Isobutyric	0.00 \pm 0.00	0.00 \pm 0.00	0.11 \pm 0.01
Isovaleric	0.13 \pm 0.01	0.30 \pm 0.01***	4.09 \pm 0.17***
Methanol	0.53 \pm 0.01	1.65 \pm 0.06***	11.06 \pm 0.11***
Ethanol vol. %	0.01 \pm 0.01	0.00 \pm 0.00	0.07 \pm 0.01
Phenylethanol	0.28 \pm 0.01	0.50 \pm 0.01***	5.11 \pm 0.11***
2-propanol	0.27 \pm 0.01	0.41 \pm 0.01***	1.87 \pm 0.07***
Isoamyl	0.11 \pm 0.01	1.56 \pm 0.07***	6.07 \pm 0.16***
Isobutanol	0.00 \pm 0.00	0.00 \pm 0.00	1.33 \pm 0.04
1-amylol	0.21 \pm 0.01	1.66 \pm 0.05***	3.08 \pm 0.14***
1-hexanol	0.00 \pm 0.00	3.55 \pm 0.06	3.96 \pm 0.17
2,3-butylenglycol	0.00 \pm 0.00	0.87 \pm 0.02	2.93 \pm 0.12
1,3-propylene glycol	1.50 \pm 0.03	4.07 \pm 0.17***	7.12 \pm 0.15***
Acetaldehyde	1.88 \pm 0.07	9.10 \pm 0.13***	17.47 \pm 0.23***
Furfural	1.17 \pm 0.01	25.45 \pm 0.22***	64.57 \pm 0.78***
Acetoin	1.64 \pm 0.01	4.11 \pm 0.19***	6.03 \pm 0.18***
Capric aldehyde	0.78 \pm 0.01	2.04 \pm 0.02***	16.00 \pm 0.33***
Methyl caprylate	0.07 \pm 0.01	1.32 \pm 0.02***	2.79 \pm 0.13***
Methyl acetate	0.00 \pm 0.00	7.81 \pm 0.13	0.00 \pm 0.00
Ethyl acetate	0.00 \pm 0.00	0.37 \pm 0.02	0.69 \pm 0.02
Ethyl butyrate	0.00 \pm 0.00	0.00 \pm 0.00	0.97 \pm 0.02
Ethyl formiate	0.32 \pm 0.01	1.50 \pm 0.01***	4.96 \pm 0.16***
Ethyl caprylate	0.00 \pm 0.00	0.37 \pm 0.01	0.70 \pm 0.01
Diacetyl	0.45 \pm 0.02	2.13 \pm 0.02***	4.09 \pm 0.11***

***P>0.001

Table 6. Concentration of volatile organic substances in the extract of kidney tissues in case of echinococcosis (M±m; n=15; mg/kg)

Organic volatile substance	Group		
	Reference	Weak infestation	Strong infestation
Acetic	91.42±0.24	52.30±0.24***	39.58±0.08***
Propionic	36.45±0.20	22.16±0.21***	13.84±0.11***
Isobutyric	0.00±0.00	0.00±0.00	2.99±0.13
Methanol	0.26±0.01	1.19±0.01***	8.99±0.13***
Ethanol vol. %	0.00±0.00	0.00±0.00	0.02±0.01
Phenylethanol	0.00±0.00	3.08±0.04	9.14±0.14
Isoamyl	0.00±0.00	0.00±0.00	1.56±0.01
1-amylol	0.00±0.00	0.00±0.00	1.30±0.01
1-hexanol	0.00±0.00	2.54±0.13	3.11±0.15
2,3-butyleneglycol	0.00±0.00	1.65±0.02	5.96±0.13
1,3-propylene glycol	1.17±0.02	3.92±0.18***	7.96±0.15***
Acetaldehyde	1.20±0.01	3.09±0.12***	9.09±0.14***
Furfural	0.00±0.00	32.56±0.23	81.40±0.25
Acetoin	2.25±0.03	3.95±0.13***	11.58±0.07***
Capric aldehyde	0.92±0.01	1.72±0.02***	13.63±0.07***
Methyl caprylate	0.00±0.00	1.67±0.01	3.05±0.15
Ethyl acetate	0.00±0.00	0.57±0.02	2.05±0.14
Ethyl formiate	0.00±0.00	3.21±0.14	7.07±0.16
Ethyl lactate	0.00±0.00	0.00±0.00	2.22±0.01
Diacetyl	0.66±0.01	5.11±0.04***	7.98±0.18***

***P>0.001

With the low degree of pigs' infestation with echinococci, the total concentration of esters was as follows: in the extract of rib eye - 1.93 mg/kg, of heart muscle - of 2.86 mg/kg, of liver - 6.16 mg/kg, of lungs - 2.59 mg/kg, of spleen - of 11.37 mg/kg, of kidneys - 5.45 mg/kg. The highest concentration of esters was noted in the extract of spleen, which was 6 times higher than in the rib eye extract, 4 times higher than in the heart muscle and lungs' extract, and 2 times higher than in the liver extract.

Among alcohols with the low degree of pigs' infestation with Echinococci, in the rib eye extract concentration of methanol and 2,3-butyleneglycol was 2 times higher, of isoamyl alcohol - 1.3 times higher than in clinically healthy animals. In the rib eye extract, concentration of 2,3-butyleneglycol was 37 times higher, of 1-hexanol - 32 times higher, of isoamyl alcohol - 18 times, of phenylethanol - 4 times higher, and of methanol - 2.5 times higher than that of isobutanol. In the cardiac muscle, concentration of methanol and isoamyl alcohol was 2 times higher than those in clinically healthy animals. Concentration of methanol was 4 times higher than that of isoamyl alcohol, and 3 times higher than that of phenylethanol.

In the tissues of liver with low degree of pigs' infestation with echinococci, concentration of methanol was 4 times higher, of 1,3-propylene glycol - 7 times higher than in clinically healthy animals. The maximum concentration among alcohols was noted for 2,3-butyleneglycol, and was 37 times higher than that of 1-hexanol, 34 times higher than that of isoamyl alcohol, 18 times higher than that of isobutanol, 11 times higher than that of 2-butanol, 9 times higher than that of methanol, 7 times higher than that of 1-amylol. In the lung tissue with low degree of pigs' infestation with echinococci, concentration of methanol and isoamyl alcohol was 2 times higher than in clinically healthy animals. The maximum concentration among alcohols was noted for methanol, and was 11 times higher than that of isoamyl alcohol and phenylethanol. Concentration of methanol and 1,3-propylene glycol was virtually the same.

With the low degree of pigs' infestation with echinococci, in the spleen tissues, concentration of methanol and

1,3-propylene glycol was 3 times higher, isoamyl alcohol - 14 times higher, 1-amylol - 8 times higher, 2-propanol and phenylethanol - 2 times higher than in clinically healthy animals. The maximum concentration among the alcohols was noted for 1,3-propylene glycol, and was 10 times higher than that of 2-propanol, 8 times higher than that of phenylethanol, 5 times higher than that of 2,3-butyleneglycol, 3 times higher than those of methanol, isoamyl alcohol and 1-amylol. In the renal tissues with low degree of pigs' infestation with echinococci, concentration of methanol was 5 times higher, of 1,3-propylene glycol - 3 times higher than in clinically healthy animals. Among alcohols, the maximum concentration was noted for 1,3-propylene glycol, and was 3 times higher than that of methanol, 2 times higher than that of 2,3-butyleneglycol, 1.5 times higher than that of 1-hexanol, and 1.3 times higher than that of phenylethanol. With low degree of pigs' infestation with echinococci, concentration of ethyl lactate (polysaccharide) in the renal tissue was 2.22±0.01 mg/kg. Concentration of diacetyl was 2 times higher in the extracts of rib eye, heart muscle and liver tissue, 1.3 times higher in the extract of lung tissue, 8 times higher in the extract of kidneys, and 5 times higher in the extract of tissues of spleen than in clinically healthy pigs (Table 6).

The research has shown that in case of high degree of pigs' infestation with echinococci, concentration of acetic acid in the rib eye was 9 times lower, of propionic acid - 33 times lower, and, on the contrary, of isovaleric acid - 16 times higher than in the clinically healthy animals. Unlike the reference group, in the experimental group, butyric and isobutyric acids were identified, which led to spoiling the products of slaughter; their concentrations were 0.12±0.01 mg/kg and 4.10±0.12 mg/kg, respectively.

In the cardiac muscle of pigs infested with echinococci, concentration of acetic acid was 8 times lower, of propionic acid - 12 times lower, of isobutyric acid - 24 times lower, of butyric acid - 18 times lower, of isovaleric acid - 6 times lower than in the clinically healthy animals. In contrast to the reference group, valeric acid was identified in the experimental group with the concentration of 1.99±0.02 mg/kg.

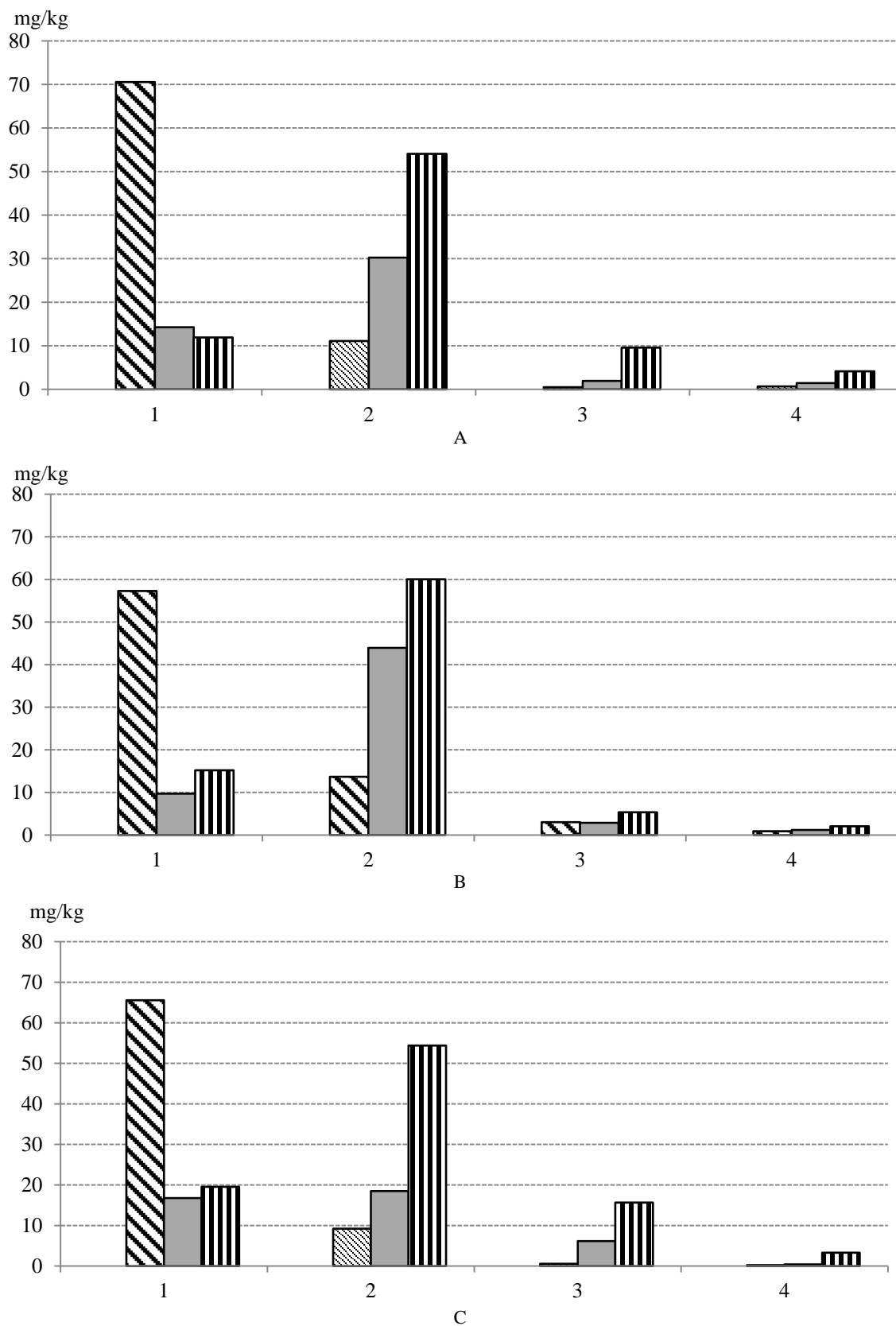


Figure 1. Content of carboxylic acids (1), aldehydes (2), esters (3), diacetyl (4) in the rib eye(A), the cardiac muscle (B) and the liver (C), as well as of volatile organic compounds in the reference group (▨), in case of weak (■) and strong (▤) pigs' infestation with echinococci

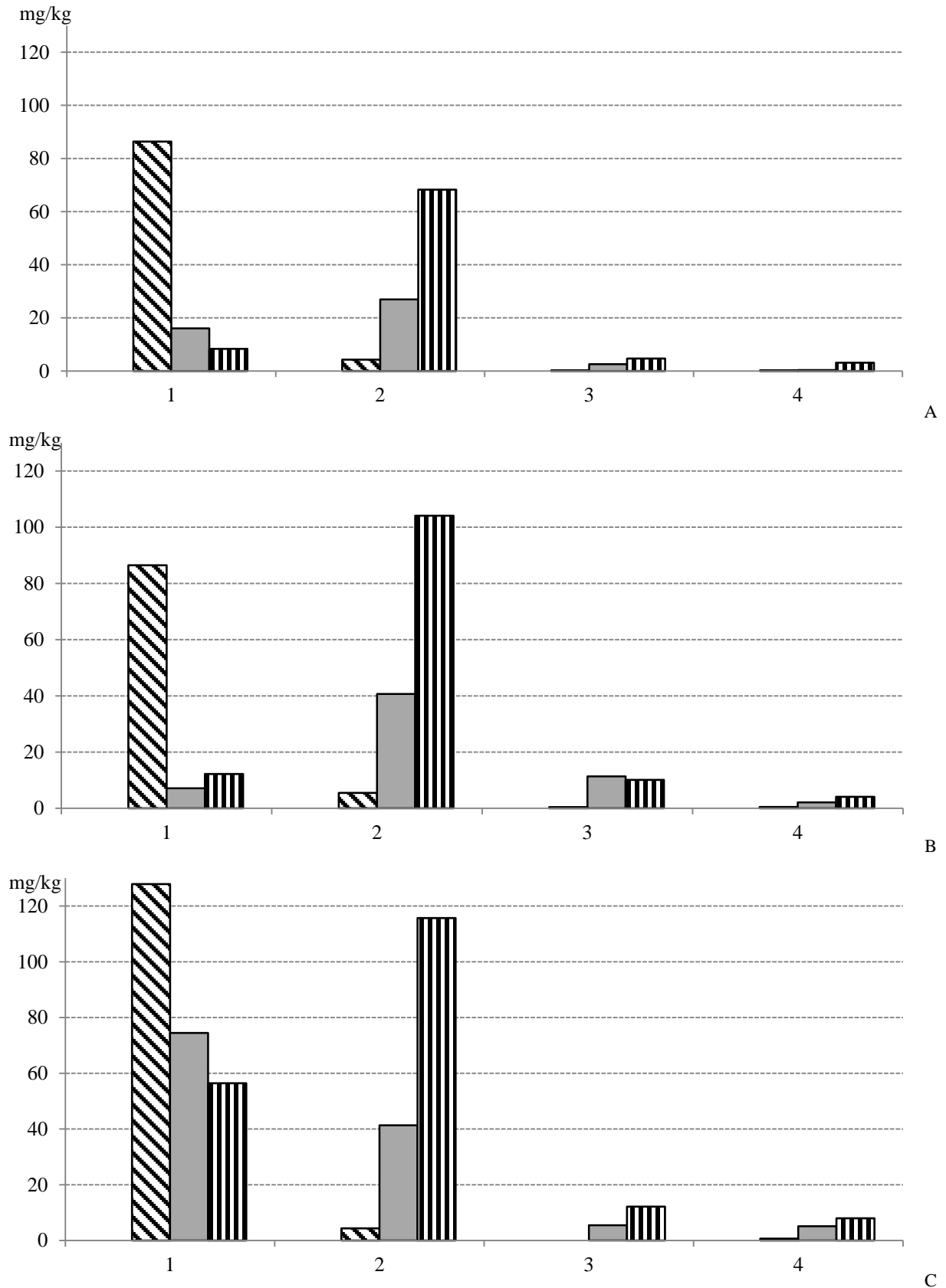


Figure 2. Content of carboxylic acids (1), aldehydes (2), esters (3), diacetyl (4) in the lungs (A), spleen (B) and the kidney (C), as well as of volatile organic substances in the reference group (▨) in case of weak (■) and strong (▮) pigs' infestation with echinococci

In the liver tissues of animals infested with echinococci, concentration of acetic and isovaleric acid was 9 times lower, of propionic acid – 3 times lower, and in the lung tissue, concentration of acetic acid was 15 times lower, of propionic acid – 77 times lower than in the clinically healthy animals. In contrast to the reference group, isobutyric acid was identified in the liver tissues in the experimental group with the concentration of 3.71 ± 0.10 mg/kg, as well as valeric acid with the concentration of 1.56 ± 0.02 mg/kg, and capric acid with the concentration of 1.73 ± 0.06 mg/kg. In the lung tissues, isobutyric acid has been detected with the concentration of 0.31 ± 0.01 mg/kg, as well as isovaleric acid with the concentration of 2.81 ± 0.06 mg/kg.

In the spleen tissues of animals infested with echinococci, concentration of acetic acid was 12 times lower, of propionic acid – 5 times lower, of isovaleric acid - 32 times lower, and in renal tissues, concentration of acetic acid was 2.3 times lower, of propionic acid – 2.6 times lower than in clinically healthy animals. Unlike reference group, in the spleen and kidney tissues in the experimental group, isobutyric acid was identified with the concentration of 0.11 mg/kg and of 2.99 ± 0.13 mg/kg, respectively.

With high degree of pigs' infestation with echinococci, in the extract of the rib eye and the cardiac muscle, the concentration of furfural was 38 times and 10 times higher, of acetaldehyde - 4 times and 5 times higher, of acetone – 1.4 times and 3 times higher, respectively, than in clinically healthy animals. In the experimental group in the extract of the rib eye and the cardiac muscle, capric aldehyde was detected with the concentration of 1.35 ± 0.01 mg/kg and 1.50 ± 0.04 mg/kg, respectively.

With high degree of pigs' infestation with echinococci, in the extract of the liver, concentration of furfural was 19 times higher, of acetaldehyde - 13 times higher, of acetone – 1.4 times higher than in the clinically healthy animals. In the experimental group, unlike the reference group, capric aldehyde was detected with the concentration of 22.39 ± 0.30 mg/kg.

In the lung tissue with strong degree of pigs' infestation with echinococci, concentration of furfural was 22 times higher, of acetaldehyde - 3 times higher than in the clinically healthy animals. In the experimental group, unlike the reference group, capric aldehyde was detected with the concentration of 22.39 ± 0.30 mg/kg, as well as acetoin with the concentration of 5.88 ± 0.18 mg/kg. In the spleen extract of animals infested with echinococci, furfural concentration was 55 times higher, capric aldehyde concentration – 21 times higher, acetaldehyde concentration - 9 times higher, and acetone concentration – 4 times higher than in the clinically healthy animals. In case of pigs' echinococcosis, in the extract of kidneys, capric aldehyde concentration was 15 times higher, acetaldehyde concentration - 8 times higher, and acetone concentration – 5 times higher than in the clinically healthy animals. In the experimental group, unlike the reference group, furfural was detected with the concentration of 81.40 ± 0.25 mg/kg that was 9 times higher than that of acetaldehyde, 7 times higher than that of acetone, 6 times higher than that of capric aldehyde. The maximum concentration of aldehydes with high degree of pigs' infestation with echinococci was noted in the extract of kidneys, which was 2 times higher than in the extract of rib eye, cardiac muscle, liver, and in the extract of lungs, and 1.1 times higher than in the extract of spleen.

In case of pigs' echinococcosis, esters were detected in the extracts of organs and tissues, the total concentration of which amounted to: in the extract of rib eye – 9.58 mg/kg, in the extract of the cardiac muscle - 5.35 mg/kg, in the extract of liver - 15.66 mg/kg, in the extract of lungs - 4.69 mg/kg, in the extract of spleen – 10.11 mg/kg, in the extract of kidneys - 12.17 mg/kg. The highest concentration of esters was detected in the extract of liver, which was 3 times higher than in the extract of the cardiac

muscle and lungs, 2 times higher than in the extract of the rib eye, 1.5 times higher than in the spleen extract, 1.3 times higher than in the extract of kidneys (Figure 1 and 2).

In the animals infested with echinococci, concentration of ethyl lactate (polysaccharide) in renal tissues was 2.22 ± 0.01 mg/kg. Concentration of diacetyl (ketone) in the extract of the rib eye was 6 times higher, in the extract of the heart muscle - 2.3 times higher, in the extract of the liver – 14 times higher, in the extract of the lungs and renal tissues - 12 times higher, in the extract of the spleen - 9 times higher than in the clinically healthy pigs. In the experimental group, unlike the reference group, methanol was detected in all organs and tissues.

CONCLUSIONS

It has been found that in the tissues and organs of pigs infested with *Echinococcus granulosus* oxidation of higher carboxylic acids had occurred, which resulted in formation and accumulation of alcohols, which, in turn, contributed to formation of acetals. The product of acetaldehyde reaction is diacetyl, which belongs to ketones; it is a yellow liquid that determines oxidation of muscle tissues and various organs, especially of the affected organ. These substances impair organoleptic characteristics of slaughter products, since they have the odor of rancid butter. During oxidation under the influence of metabolic processes of *Echinococcus granulosus* in the muscle tissues and various organs of the animal, excessive acetoin accumulated. Furfural generated in large concentrations gave the odor of overheated bran that deteriorated the quality of the slaughter products. In case of pigs' echinococcosis, the total concentration of carboxylic acids in all organs and tissues of pigs was 4 times lower, while, on the contrary, the total concentration of aldehydes was 9 times higher, and overall concentration of esters – 12 times higher than in the clinically healthy animals.

Thus, it has been found that in case of high degree of pigs' infestation with echinococci, compared to the clinically healthy animals, intermediate products of volatile organic compounds' decomposition were intensively forming, resulting in deterioration of the quality of products of animal slaughter.

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