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Agriculture and Environment

Animal hygiene and ecological assessment of air pollution in a pig-farm

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Abstract. *The aim of this study was to determine air pollution with ammonia, hydrogen sulfide, total dust, microorganisms (saprophytic and coliform bacteria, including Escherichia coli) from a pig farm for 50 sows (average daily capacity 532 pigs from different categories). The pollutants were investigated in five points as follows: emissions from production buildings - Point 1 (P_1) - building for farrowing sows and Point 2 (P_2) - building for fattening pigs; imissions in ambient air- Point 3 (P_3) - at 2 m, and Point 4 (P_4) - at 50 m distance from the buildings under the wind side position, and Point 5 (P_5) - at 10 m distance - over the wind side position of the farm. The levels of the hydrogen sulfide (3.31-7.10 $mg.m^{-3}$), total dust (0.71-5.11 $mg.m^{-3}$) and number of cultivable microorganisms (13,0 x 10^3 - 428,0 x $10^3/m^{-3}$) in the air of the buildings (P_1 and P_2) were within the animal hygiene requirements, except the ammonia (3.32-15.82 $mg.m^{-3}$) which concentrations exceeded the norm. The air quality for the staff as a factor of working environment in the buildings covered all requirements. Emissions of NH_3, H_2S, total dust and microorganisms from the farm buildings maintain measurable concentrations of these pollutants (imission) at 50 m leeward and at 10 m over wind side of the farm. With increasing the distance from the production buildings contents of NH_3, H_2S, dust and microorganisms in the air decreased from 1.4 to 13.7 times at P_4 and from 1.4 to 16.7 times at P_5. The air quality around the pig farm did not correspond with the norms at P_4, and at P_5, regarding the content of ammonia and total dust. For the content of hydrogen sulfide that finding applies to P_3 and P_5. Statistical differences (P Ў 0.05 – 0.001) were established at the levels of the investigated pollutants of the air between seasons (summer, autumn, winter) in the same point and between different points at the same season.*

Keywords: pig-farm, air, pollution, assessment

Abbreviations: BSS–Bulgarian state standard, TCCM – Total count of cultivable microorganisms, NCfB – Number of coliform bacteria, CFU – Colony forming units, CT – Coefficient of technogenic, MPC – Maximum permissible concentration, $MPC_{av.d.c.}$ – $MPC_{average\ daily\ concentration}$, $MPC_{m.s.c.}$ – $MPC_{maximum\ single\ concentration}$.

Introduction

Livestock production systems are also prone to the general problems of pollution such as those emanating from industrial activities. Among them, occupy a special place pig-farms, which are the most significant sources of emissions, potential pollution of air, soil, surface and groundwater. According to Pain (1994) pig farms are the largest source of emissions accounting for 57% of all emissions from livestock, followed by poultry farms (22%), cattle farms (17%) and horse farms (4%).

The air pollution from the pig-farms can have harmful effects on both animals and staff of the pig-farm and the natural and urban ecosystems around those units (Nielsen et al., 1991; Jacobson, 1993; Hartung and Philips, 1994; Verstagen et al., 1994; Cherny, 1997; Petkov, 2004). The emissions of noxious odours (ammonia, hydrogen sulfide, phenol, methyl mercaptan), dust and microorganisms vary widely and depend on the capacity of the farm, system of cleaning and storage of manure, ventilation system, other factors (Rusak and Rokicki, 1985; Nielsen at al., 1991; Verstagen at al., 1994; Petkov, 2006).

In recent years research in the pig-farms are focused mainly on emissions of ammonia, one of the most serious environmental contaminants (Monteny, 1994; Aarnink, 1997; Canh, 1998; Ivanova-Peneva et al., 2006, 2007, 2008). Oudendag (1993), found that ammonia emissions from livestock are almost 50% of all emissions, as 13% of them are from pig-farms. These investigations correspond with European Commission Acidification Strategy and the EU Directive 2001/81/CE, whereby all EU countries should limit of ammonia emissions from livestock farming. At the same time a number of studies at abroad (Crook et al., 1991; Madec, 2001; Hamscher et al., 2003) and in Bulgaria (Petkov and Baykov, 1988; Katsarov et al., 2001; Petkov, 2004, 2005) reveal that pig-farms, in addition to ammonia, are source of emissions of hydrogen sulphide, dust and microorganisms. The data shows that these pollutants open questions concerning the quantities of emissions from the production buildings, their dispersion (migration) into the air and their impact on organisms and ecosystems around the pig-farms. A fact which should not be underestimated.

On the other hand, the new environmental legislation of the country, harmonized with the EU, sets new requirements for environmental quality. Standards have adopted for sanitary protection zones of the settlements (Regulation № 7/1992) and for air quality in the buildings for different species and categories of animals (Regulation № 44/2006), the working environment (Regulation № 13/2003) and the ambient air of settlements (Regulation № 14/1997).

These arguments motivated the conduct of this study, the aim of which was to investigate air pollution with ammonia, hydrogen sulfide, total dust, microorganisms from a pig farm for 50 sows and to make animal hygiene and ecological assessment of air quality in buildings and outside, in the boundaries of hygienic protection zone of the farm.

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Material and methods

1. General description of the pig farm

The study was done on a pig farm with capacity 50 sows, from July 2009 to March 2010. The farm was located in a former farmyard in south-east direction, outside of housing regulation at village Trilistnik (Central part of Bulgaria, region of Plovdiv) on area of 2670 m^2, of which 900 m^2 built area. All production buildings - № 1, № 2, № 3, as a form of a monoblock were situated parallel to each other in direction east-west. The buildings were with the same dimensions - length 24.00 m, width 9.00 m, height - 2.50 m, and width of service alleys 1.00 m. The western side of the monoblock was connected by a common corridor with offices - household sector, forage stores, feed kitchen, office and veterinary surgery (Figure 1).

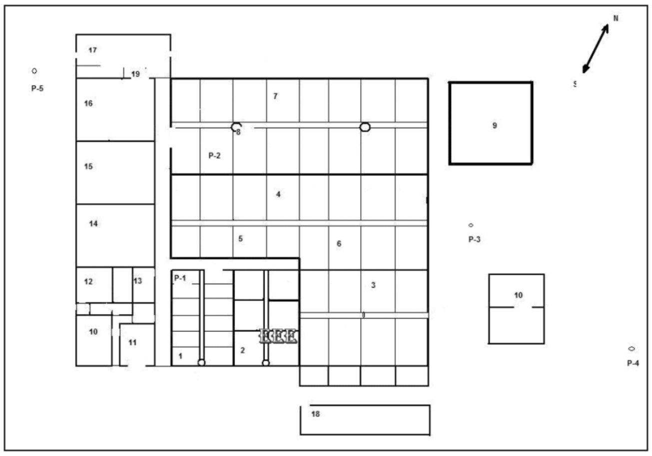

Figure 1. Layout of pig farm
Legend: Pig-farm: 1–Sows and litters; 2–Pprenursery and nurserypigs pigs; 3–Growing pigs; 4–Sows; 5–Boars; 6–Yards for a walk; 7–Fattening pigs; 8–Fan; 9–Tank for liquid manure; 10, 11,12 and 13–Offices; 14, 15 and 16–Feed stores; 17–Weighing machine; 18–Workshop; 19–Water pump.
Points for sampling air: P_1–Building for sows and litters; P_2–Building for fattening pigs; P_3–at 2 m and P_4 at 50 m *distance from the leeward of the production buildings*; P_5–at 10 m from wind over side of the *production buildings*.

In the farm yard there were silos for storing grain, shed with scales, ramp for loading/unloading of animals and service. The manure storage place, with capacity of 1000 m^3 was located in the east part of the farmyard. Until it has two underground tanks (800 m^3 each of them) for the collection of wastewater from the production buildings. Water for drinking and technological needs of the farm was provided by own well drilling, a depth of 10 m and flow rate 60 l/s, located in the northwestern part of the yard. During the study average number of pigs housed in the farm was 532, broken down by category as follows: sows – 50 (45 basic and 5 repairs), boars - 4, prenursery and nursery pigs - 82, growing pigs - 123, fattening pigs - 273.

Building № 1. The building includes three rooms – for sows and litters, prenursery and nurseryp pigs and for growing pigs. Premises for sows and litters includes 12 pens for farrowing sows, located in two rows (6 x 6) on both sides of a central service alley. Each pen was built of a plastic slotted floor (two concrete channel underneath to collect the manure and waste water), plastic walls, a metal clamp for sows with feeding and drinking troughs. In the floor were installed heating panels to maintain the required temperature for newborn pigs. On the rear wall of the pen was installed drinker for piglets and mobile feed for granular feed. The ventilation of the premises for sows and litters was negative pressure system. A fan (with capacity 6000 m^3/h), mounted in the shaft of the roof ridge, blow air out the premises, creating a slight negative pressure (vacuum) to draw air into the premises throw two designed inlets, located on both sides over farrowing pens. The volume of incoming air (m^3/h) was automatically regulated by a thermostat.

Premises for prenursery and nursery pigs include 6 pens, located in two rows (3 x 3) on both sides of a central service alley. The equipment of each pen include totally slotted floor, plastic partition walls, heating panels, hopper feeders, with two places for eating and automatic drinker between them. Feeders was loaded manually. Pigs were kept in group pens (18-21 pigs in a pen). Ventilation was the same as in premises for sows and litters.

Premises for growing pigs occupy half the area of the building № 1. It includes 8 pens, located in two rows (4 x 4) on both sides of a central service path. The pens were built with concrete floor and walls. Between any two pens was mounted bunker feeder, loaded manually. Watering was done with nipple drinkers. Every pen has connected to an outside yard, size 2.50 x 3.00 m, with rubber mesh curtains. Ventilation was natural – by the windows and doors. This system moves air through a room with wind pressure differences between inlets and outlets, and differences between inside and outside temperatures.

Building № 2. This building was for pregnant sows and boars. Pregnant sows were kept in 8 group pens (3.00/4.50 m, 5-6 sows in a pen) with concrete solid floors and concrete walls. Animal nutrition was on the floor, with manual loading of food. The cleaning of pens was manually and daily. Watering was performed by nipple drinkers. Ventilation was natural – through the windows and doors. Boars were kept in 4 individual pens (3.00/2.00 m) with concrete solid floor and walls.

Building № 3. The building was designed for fattening pigs. This category of pigs was kept in 16 groups pens (3.00/4.00 m, 15-18 pigs in a pen). The pens were located in two rows (8 x 8) on both sides of a central service alley. They were built with combined floor (1/3 concrete solid part and 2/3 plastic slotted part) and plastic walls. Each pen was connected to an outside yard for a walk. Feeding was done by hopper feeders mounted between two pens. Charging the feed was automatically by chain-stopper conveyor. Watering was performed by nipple drinkers. The ventilation of the building was negative pressure system. Two fans (each of them with capacity 11 000 m^3/h), located above the central service alley blow air out the building, creating a slight negative pressure to draw air into the building throw 12 designed inlets (0.53/0.35 m) located on both sides over the pens. The work of fans and the size of the openings of vent valves shall be adjusted automatically, depending on the inside air temperature. During the hot summer months worked cooling system that sprayed jets of water through the form of fog over each pen.

Manure management. The system of manure handling was based on its separation into two fractions - solid (faeces) and liquid (a mixture of urine and waste water). Buildings, where pigs were kept in pens with solid floors, solid manure was cleaned by hand and wheelbarrow were transported to the place storage manure. Urine and technological waste waters, by system of channels was transported to the underground concrete tanks. Buildings, where pigs were raised in pens with slotted or partly slotted floors the solid manure was collected in the channels under the floors. After filling the channels, the manure was cleaned manually. The liquid fraction was transported by channels to the tanks. Collected solid and liquid manure was used as fertilizer of the soil with fodder plants around the pig-farm.

2. Study area

2.1. Investigated indicators

It was studied the following indicators, characterizing air quality: Ammonia (NH_3), Hydrogen sulfide (H_2S), Total dust, Total count of cultivable microorganisms (TCCM) and Number of coliform bacteria (NCfB).

2.2. Points for sampling air

Were down 5 points for sampling air:

– for *emission* control (air in the buildings): *point 1* (P_1) - in the building for sows and litters (Building №1) and *point 2* (P_2) - in the building for fattening pigs (Building №3);

– for *imission* control (ambient air): *point 3* (P_3) - at 2 m and *point 4* (P_4) - at 50 m distance from the leeward of the production buildings; *point 5* (P_5) - at 10 m from wind over side of the production buildings.

2.3. Samples collected

Designated points once a month in the same sequence, the time between 13.00 and 15.00 h, were collected two parallel air samples for testing of ammonia, hydrogen sulfide, total dust, number of cultivable of microorganisms and number of coliform bacteria. The total number of collected air samples was 450. At points 1, 2 and 3, during the sampling air were measured: Temperature, Relative humidity and Air velocity.

2.4. Methods for analysis of survey indicators of air

Physical parameters: Temperature(°C)-with mercury thermometer in BSS 8451-77, Relative humidity (%)- by psihrometar of Asman, Air velocity ($m.s^{-1}$) - by katatermometer (Petkov at al., 1999);

Chemical parameters: Ammonia (NH_3), ($mg.m^{-3}$) - titrimetrically, with hydrochloric acid (Petkov at al., 1999); Hydrogen sulfide (H_2S), ($mg.m^{-3}$)- titrimetrically with sodium thiosulphate (Petkov at al., 1999); Total dust ($mg.m^{-3}$) – by gravimetric method (BSS 17.2.4.20-83);

Microbiological indicators:

a) Total count of cultivable microorganisms – TCCM (CFU/m^{-3} air) - by sedimentation method onto plates with Nutrient Agar (BBL®, USA). The plates were incubated for 24 h at 30±1°C under aerobic conditions. (Smith, 1980; Danon-Moshe et al., 1985);

b) Number of Coliform Bacteria, including *Escherichia coli* - NCfB (CFU/m^{-3} air) - by sedimentation method onto plates with Endo Agar (BBL®, USA). The plates were incubated for 24 h at 37±1°C under aerobic conditions. (Smith, 1980; Danon-Moshe et al., 1985).

2.5. Animal-hygienic and ecological evaluation of the air quality

The animal-hygienic and ecological evaluation of the air in the pig-farm was performed by method of comparative analysis, where the obtain results were compared with referents values in the national rules for air quality as follow: for pig breeding (Regulation № 21/2005; Regulation № 44/2006); for working environment of the staff (Regulation № 13/2004); for atmospheric air (Regulation № 14/1997). Ecological assessment of air quality, regarding content of NH_3, H_2S and total dust was made using the Coefficient of Technogenic (CT), calculated by formula (Chernikov and Chekeres, 2000):

CT = C/ MPC, where:

CT– Coefficient of technogenic, (CT $_{\circ}$ 1, when no technogenic impacts and air quality meets the requirements);

C – Concentration of pollutant in the air, ($mg.m^{-3}$ air);

MPC – Mximum permissible concentration of the pollutant in the air, ($mg.m^{-3}$ air).

In legal documents there aren't norms for number of microorganisms (saprophytic, pathogenic) in the air at the working environment (in the buildings) and in atmospheric air. For these indicators, we adopted the norms proposed by some authors published in the scientific literature (Petrova and Gabev, 1974; Kichatova, 1969, in Danon-Moshe et al. 1985).

To take into account the simultaneous action of ammonia and hydrogen sulphide (gases with unidirectional irritating effect on the body) in the air of pig-farm (i.e. air in the work environment) on staff was calculated a *Complex Coefficient* (CC) by method and formula according Regulation № 13/2004:

$C_1 / MPC_1 + C_2 / MPC_2 = CC$, where:

CC –Complex Coefficient (It is normal when CC≤1);

(C_1)–NH_3, respectively (C_2) - H_2S concentration in the air, ($mg.m^{-3}$ air);

(MPC_1), (MPC_2) – Maximum permissible concentration of NH_3, respectively H_2S in the air of working environment, ($mg.m^{-3}$ air). MPC_1 = 18 $mg.m^{-3}$ and MPC_2 = 14 $mg.m^{-3}$ by Regulation № 13 (2004).

3. Statistical analysis

The data obtained were analyzed using the Program STATISTICA, StatSoft, SAS, 1989.

Results and discussion

Physical parameters of air

Date about temperature, relative humidity and air velocity inside and outside of the studied buildings are presented in Table 1. Animal hygiene evaluation of the air quality, made on the base of the norms in Regulation № 44 (2006) for veterinary requirements for holdings and Regulation №21(2005) for minimum requirements for protection and welfare of pigs, showed that:

– The air temperature in the building for sows and litters (P_1) throughout the study was within the norm (18.0 - 27.0 °C). In the building for fattened pigs (P_2) in four out of nine months of the experimental period, the temperature was outside the limits (below 15.0 °C in October and November, and over 22.0 °C in July and November).

– The relative humidity in the building for sows and litters (P_1) for most of the period of study was within normal limits (60-85%), except October and December, when it exceeded the requirements. In the building for fattening pigs (P_2) relative humidity values exceeded the upper limit only in December (98.4%). All other values were within the animal hygiene requirements.

– The air velocity in both buildings - P_1 and P_2 was in the range of the hygiene standards (0.2-0.5 $m.s^{-1}$).

In respect of outside air (P_3) established values for temperature, relative humidity and air velocity were normal in the month of the year for the climate zone in which the pig-farm was located. Although the results of controlled physical parameters of air are practically instantaneous values, because they are determined during the sampling air, they have a direct connection and importance of accumulation and migration of ammonia, hydrogen sulfide, dust and microorganisms in the air of production buildings and outside of them.

Chemical indicators of air

Ammonia. A. Emissions. The concentration of ammonia into the

Table 1. Temperature (T °C), Relative humidity (R – %) and Air velocity ($m.s^{-1}$) in the investigated pig farm

Season	Physical indicators of air								
	Points								
	P_1 *			P_2			P_3		
	T °C	R %	V m/s	T °C	R %	V m/s	T °C	R %	V m/s
Summer (n = 3)	24.0±2.1	81.6±4.1	0,69±0,23	25.0±5.4	80.4±3.3	0.85±0.21	23.0±5.8	72.5±7.9	1.80±1.93
Autumn (n = 3)	20.3±2.8	87.9±3.8	0,11±0,15	15.0±5.1	89.3±4.1	0.05±0.01	11.3±5.1	77.0±6.1	0.49±0.21
Winter (n = 3)	19.9±3.1	78.9±3.7	0,24±0,11	14.6±4.0	83.3±4.6	0.43±0.29	7.96±6.2	76.7±5.2	0.57±0.21
Av. for the period (n = 9)	21.4±3.3	82.8±4.4	0.34±0,23	18.2±5.6	84.3± 4.7	0.44± 0.30	14.1±6.2	75.4±7.7	0.95±1.35
Min	19.4	77.8	0.04	9.0	78.2	0.04	4.4	64.9	0.04
Max	25.0	94.6	1.18	28.0	98.4	1.37	25.0	85.7	2,02
Animal Hygiene Norm**	18-27	60-85	0.2-0.5	15-22	60-85	0.2 -0.5	-	-	-

*P_1 - building for farrowing sows, P_2 - building for fattening pigs, P_3 – outside, at 10 m distance from the buildings;
** According Regulation № 44/2006 on veterinary requirements for holdings and Regulation № 21/2005 on the minimum requirements for the protection and welfare of pigs.

air of the studied buildings ranged considerably on months, but slightly by seasons (Table 2). In the building for sows and litters (P_1) ammonia level was higher than that in the building for fattening pigs (P_2) - from 1.43 times in winter to 1.71 times in the summer, average for the period by 1.43 times. The main reason for this result is a larger number of animals kept in building for fattening pigs compared to building for sows and litters. The obtained results for ammonia in the air of buildings for different categories of pigs were in the range of values reported by Coleman et al. (1991) - 3.5-18.0 $mg.m^{-3}$ and higher than the values established by Petkov (2004, 2006) in previous studies in pig farms for 35 and 490 sows, respectively from 3.30 to 6.56 $mg.m^{-3}$ air.

In seasons the levels of ammonia in the buildings (P_1 and P_2) was highest in winter, while in terms of the lowest concentrations no unification of the results. In P_1 ammonia concentration was with lowest values in the summer and in P_2 - in the autumn. Differences in seasonal values of ammonia in both buildings were demonstrated (at P ∘ 0.05 - P ∘ 0.001) under the following options (summer-winter, autumn-winter for P_1 and summer-autumn, autumn-winter for P_2). Results for seasonal dynamics of ammonia in the air of the buildings were in one way to those of Aarnink (1997) and partially coincide with the date obtained by Petkov (2004, 2006).

Comparison of results for the ammonia in the air of production buildings by animal hygiene standards for pigs (up to 3.5 $mg.m^{-3}$ air, Regulation № 44/2006) indicates that in the building for sows and litter the ammonia content exceed the rate of 1.99 times during the summer to 2.62 times during the winter and in the building for fattening pigs, respectively from 2.71 times in the autumn to 4.12 times in the summer. Therefore, the air quality in the buildings (P_1 and P_2) didn't correspond with the norms. Assessment of air quality in the buildings, as a factor of the workplace (according Regulation № 13/2004, MPC - 14.0 $mg.m^{-3}$), shows that in both buildings ammonia concentrations were within normal limits.

The established concentrations of ammonia in the air of the buildings were actually emissions of this gas as by ventilation inside air, contaminated with ammonia, was discharged outside and pollute ambient air. Data analysis showed that ammonia emissions from the buildings were significant quantities- building for sows and litters (P_1) from 3.32 to 11.44 $mg.m^{-3}$ air and building for fattening pigs (P_2) from 7.93 to 15.82 $mg.m^{-3}$ air.

B. Immission. The content of ammonia in ambient air was highest at 2 m to leeward of the farm (P_3), average for the period 5.74 $mg.m^{-3}$ air and lowest at 50 m in the same direction (P_4), average for the period 3.18 $mg.m^{-3}$ air. In point P_5 – at 10 m from wind over side of the farm the content of ammonia was with intermediate values (Table 2). In practice, the established values for ammonia in the controlled points around the farm were immission of this gas. On seasons the level of ammonia in the air at controlled points around production buildings varied in a similar way as in the buildings. In all outside points ammonia concentrations were highest in winter and lowest in autumn at points P_3 and P_5, and in the summer - in point P_4. In seasons differences between controlled points (P_3, P_4 and P_5) were unreliable, except combinations summer-winter, autumn-winter in point P_4, where differences were shown at $P \leq 0.05$.

With increasing the distance from the production buildings contents of ammonia in the air decreased compare to the buildings (P_1 and P_2), average for the period of study as follows:

– at points in the leeward of the farm: in P_3 at 2 m distance from the buildings – from 1.4 to 1.9 times; in P_4 at 50 m - from 2.5 to 3.36 times;

– at the point of wind over side of the farm - P_5, at 10 m distance from the buildings - from 1.9 to 2.5 times.

It should be noted that in P_3 the content of ammonia in the air decreased from 28.4 to 46.3% compared to the buildings, but remains relatively high. The results give reason to believe that most influence on these concentrations of ammonia were emissions from the production buildings of the farm. All differences between the quantity of ammonia in both buildings (P_1 and P_2), on the one hand, and that at points around the buildings (P_3, P_4 and P_5), on the other, were demonstrated at $P \leq 0.01$ – $P \leq 0.001$. On the formation of ammonia and its accumulation in the air of the production buildings and on its migration into the air around the farm, influence also the specific microclimatic conditions / meteorological factors -

Table 2. Content of ammonia and hydrogen sulfide in the air of the pig farm

Season	Points				
	P_1*	P_2	P_3	P_4	P_5
			Ammonia (NH_3), $mg.m^{-3}$ air		
Summer (n = 6)	Aa 6.97±2.47	b 11.94±1.32	Ac 5.36±2.14	d 2.47±1.21	Ae 4,51±0.92
Autumn (n = 6)	Ba 7.93±0.62	B 9.50 ±0.48	c 5.08±1.36	Cd 2.65±1.94	Ce 3,73±0.80
Winter (n = 6)	D 9.17±0.89	b 13.12±1.38	Dc 6.79±1.92	E 4.44±0.84	Ee 4,55±0.40
Av. for the period (n = 18)	F 8.02±1.26	F 11.52±1.96	G 5.74±0.92	G 3.18±0.70	G 4,26±0.39
Min	3.32	7.93	1.62	0.00	1,66
Max	11.44	15.82	10.12	6.28	9,74
Animal Hygiene Norm **	5 ppm (3.5 mg/m^3)	5 ppm (3.5 mg/m^3)	-	-	-
Working conditions Standard ***	14.0	14.0	-	-	-
Air quality Standard for the settlements ****			0.1 [I] 0.25 [II]	0.1 0.25	0.1 0.25
			Ammonia (NH_3), $mg.m^{-3}$ air		
Summer (n = 6)	Hf 2,63±0.98	g 5,34±0.44	H 1,23±0.47	***** NP	H 2,06±0.91
Autumn (n = 6)	If 3,26±0.55	g 5,64±1.44	Ih 2,41±0.05	NP	0,27±0.33
Winter (n = 6)	Jf 3,40±0.21	g 5,79±1.26	Jh 2,45±0.32	NP	0,89±0.14
Av. for the period (n = 18)	3.09±0.68	5,59±0.86	K 2,03±0.27	NP	K 1,07±0.40
Min	0,00	3,31	0,00	-	0,00
Max		7,10	3,30	-	3,30
Animal Hygiene Norm **	Not allowed 4,88	Not allowed	-	-	-
Working conditions Standard ***	14.0	14.0	-	-	-
Air quality Standard for the settlements ****	-	-	0.003 [I] 0.005 [II]	0.003 0.005	0.003 0.005

* P_1 - building for farrowing sows, P_2 - building for fattening pigs, P_3 - at 2 m, and P_4 - at 50 m from the leeward of the production buildings, P_5 - at 10 m from wind over side of the production buildings;
** According Regulation № 44/2006 on veterinary requirements for holdings;
*** According Regulation № 13/2003 on the limit concentrations of harmful substances in the air in the working environment;
**** According Regulation № 14/1997 on the limit values for concentrations of pollutants in the atmospheric air of settlements
(I – Average daily permissible concentration; II - Maximum permissible concentration;
***** NP - Not Proven;
Differences among the values are statistically significant at P ≤ 0.05 if have not equal – capital letters by rows and small letters by columns.

temperature, relative humidity and air velocity.

Expressed by coefficient of technogenic (CT), calculated on the basis $MPC_{av.d.c.}$ - 0.1 $mg.m^{-3}$ air and $MPC_{m.s.c.}$ - 0.25 $mg.m^{-3}$ air (according Regulation № 14/1997), the degree of air pollution in the points around the farm buildings, on average for the period was as follows:

– at P_3 – CT = 23.0 on $MPC_{av.d.c.}$ and CT = 11.5 on $MPC_{m.s.c.}$;
– at P_4 – CT = 10.1 on $MPC_{av.d.c.}$ and CT = 6.4 on $MPC_{m.s.c.}$;
– at P_5 – CT = 17.4 on $MPC_{av.d.c.}$ and CT = 8.5 on $MPC_{m.s.c.}$.

As regards the requirements for ambient air quality in urban areas (Regulation № 14/1997) it was established that the air up to 50 m from the production buildings didn't meet the requirements for ammonia content, as CT > 1. The greatest deviations from the standard were at P_3, followed by those in P_5 and P_4.

Hydrogen sulphide. *A. Emissions*. The concentration of hydrogen sulfide in the air at the building for sows and litters ranged from 2.63 $mg.m^{-3}$ in the summer to 3.40 $mg.m^{-3}$ in winter, and in building for fattening pigs – from 5.34 $mg.m^{-3}$ in the summer to 5.79 $mg.m^{-3}$ in winter (Table 2). Noticed that the hydrogen sulphide content varies slightly in the air in the both buildings. This suggests that factors in the buildings, which influence the formation of hydrogen sulphide did not change significantly in different seasons. At the same time was very well marked difference in the content of hydrogen sulfide between P_1 and P_2. In the building for fattening pigs (P_2) the level of hydrogen sulphide was twice higher than that in the building for sows and litters (P_1) - from 1.70 times in winter to 3.27 times in the summer. Average for the period difference was reliable at $P \circ 0.05$. Here, as in ammonia, the impact of a larger number of animals in the building for fattening pigs was essential factor for higher levels of hydrogen sulfide in the air. These results were within the limits set by us in exploring other farms with a capacity of 490 sows (3.18 to 6.66 mg/m^3) and 35 sows (3.22 to 6.12 mg/m^3), (Petkov, 2004; 2006). The data give reason to conclude that regardless of the capacity and location of the farm, the factors that influence the formation of hydrogen sulphide in the production buildings for various categories of pigs are similar and close in magnitude of impact. On seasons in both buildings (P_1, P_2) the level of hydrogen sulphide in the air was highest in winter and lowest in summer. The results were opposite to those obtained in other, earlier studies on the problem in which the highest content of hydrogen sulfide in the air of buildings for different categories of pigs are found in summer, and the lowest – in winter (Petkov, 2004; 2006). For minor variation in the values measured concentrations of hydrogen sulphide in different seasons, assuming that receipt of such contradictory results is possible and explicable.

Animal hygiene assessment of the air in the buildings shows that air quality did not meet the requirements of Regulation № 44/2006, since according to this normative document in the air of pig production buildings should not have hydrogen sulfide. In assessing air quality in terms of hygiene requirements for working conditions of staff was found that hydrogen sulphide concentrations were below the MPC for workplace air (up to 14.0 $mg.m^{-3}$, Regulation № 13/2004) from 5.3 to 8.6 times in P_1, and from 2.6 to 2.4 times in P_2. Emissions of hydrogen sulfide from the investigated buildings of the farm were significant and ranged as follows: building for sows and litters (P_1) up to 4.88 $mg.m^{-3}$ and building for fattening pigs (P_2) from 3.31 to 7.10 $mg.m^{-3}$.

B. Immission. The content of hydrogen sulfide in ambient air was highest at 2 m (P_3), average for the period 2.03 $mg.m^{-3}$ air. At 50 m (P_4) in any sample did not prove the presence of this gas. In the P_5, to 10 m the content of hydrogen sulphide per period was 1.07 $mg.m^{-3}$ air (Table 2). On seasons, the concentration of hydrogen sulfide in controlled points was different. In P_3 the highest values were in summer and lowest in autumn. In P_5 was back, the highest values were in winter and lowest in summer. This inconsistency of the results give reason to suppose that the formation, accumulation and diffusion of hydrogen sulphide in the air at various points has affected by many factors of which combine depends on what concentration of this gas will be maintained.

With increasing the distance from the production buildings contents of hydrogen sulphide in the air reliably reduced (at $P \leq 0.05$ - 0.001) compared to that in the buildings (P_1 and P_2), average for the period as follows: at P_3 to leeward of the farm - from 1.1 to 5.2 times and at P_5 of wind over side of the farm - from 1.4 to 2.4 times.

Expressed by coefficient of technogenic (CT), calculated on the basis $MPC_{av.d.c.}$ - 0.003 $mg.m^{-3}$ and $MPC_{m.s.c.}$ - 0.005 $mg.m^{-3}$

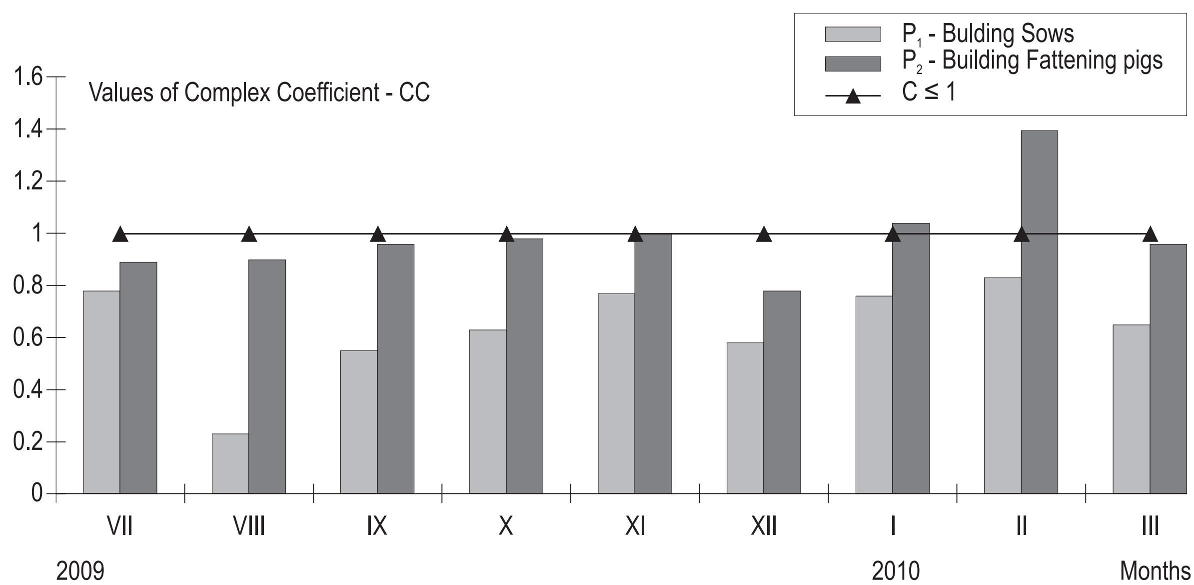

Figure 2. Values of the Complex Coefficient (CC), taking into account the combined effects of NH_3 and H_2S in the air in production buildings on staff of the farm

(Regulation № 14/1997), the degree of air pollution in the investigated points around the farm buildings, on average for the period were as follows:

– at P_3 – CT = 676.7 on $MPC_{av.d.c.}$ and CT = 406.0 on $MPC_{m.s.c.}$;

– at P_4 – CT = 0;

– at P_5 – CT = 365.6 on $MPC_{av.d.c.}$ and CT = 214.0 on $MPC_{m.s.c.}$.

As regards the requirements for ambient air quality in urban areas (Regulation № 14/1997) it has established that the air up to 10 m around the farm did not qualify for hydrogen sulfide (CT > 1). The greatest deviations from the norms were in P_3 and the lowest in P_4. At 50 m from the farm the air quality was within normal limits on this indicator.

Assessing air quality in the working environment while the presence of ammonia and hydrogen sulfide in the air. In the study it was found the presence of both ammonia and hydrogen sulfide in the air in the working environment (production buildings of the farm – P_1 and P_2). This required an evaluation of the air quality on the complex coefficient (CC) by Regulation № 13 (2004). The results showed that in both buildings (P_1 and P_2) the values of the coefficient (CC) were less than one (C < 1), i.e. they have met the requirements of law. Exception of January and February, when in the building for fattening pigs index values were greater than one (CC > 1), a circumstance where there is increased risk to the health of staff (Figure 2).

Dust. A. Emissions. The amount of dust in the air at the building for sows and litters ranged from 1.28 $mg.m^{-3}$ in winter to 2.62 $mg.m^{3}$ in summer, and at the building for fattening pigs - from 1.37 $mg.m^{-3}$ in the summer to 4.35 $mg.m^{-3}$ autumn (Table 3). In P_1 dust in air was greater than that in P_2 - from 1.70 times in winter to 3.27 times in the summer. The obtained results confirm the results, obtained by Hamscher et al. (2003) and Petkov (2004, 2006) and showed that regardless of the capacity and location of the farm, the factors that affect dust pollution of the air in buildings for different categories pigs are similar and close in magnitude of impact. In seasons the level of dust in the air of the both points (P_1, P_2) was characterized by diverse developments. In the building for sows and litters the dust in the air was greatest in summer and least in winter, while in the building for fattening pig values were highest in autumn, while the lowest - in summer. The differences in seasonal values between P_1 and P_2 were statistically reliable in all combinations at $P \leq 0.05$. The differences between all seasonal values in point P_2 were statistically prove at $P \leq 0.05$, and between combinations summer-winter, autumn-winter in point P_1 (at $P \leq 0.05 - 0.01$).

Animal hygiene assessment of the air in the buildings of the farm, referring the dust content, showed that the air quality meets the requirements of Regulation № 44/2006, since all established values were within the permissible norm – up to 5.0 $mg.m^{-3}$. An exception was the maximum value for the dust in the building for fattening pigs, which was higher than limit. Air quality meet the hygiene requirements for working conditions for staff as identified concentrations were lower (from 1.1 to 3.9 times) of the MPC for workplace air (up to 5.0 $mg.m^{-3}$ by Regulation № 13/2004).

Dust emissions from the investigated buildings were in the diapason as follow: building for sows and litters (P_1) – from 1.46 to 4.98 $mg.m^{-3}$ and building for fattening pigs (P_2) - from 0.71 to 5.11 $mg.m^{-3}$.

B. Immissions. In the points for control of ambient air around the farm (P_3, P_4 and P_5) the dust content in the air (immissions) was highest at 2 m from the leeward of the farm - P_3 (in different seasons - from 0.86 to 1.76 $mg.m^{-3}$) and lowest in P_4 at 50 m in the same direction (from 0.67 to 0.90 $mg.m^{-3}$). In point P_5 at 10 m of wind over side of the farm the dust content was with intermediate values (Table 3). In season, the quantity of dust in all outside points was less in winter than the other two seasons (summer and autumn), when the results were very similar. Differences in values of dust between seasons in the three points were statistically prove at $P \leq 0.05 - 0.01$, with the exception of summer-autumn option.

With increasing the distance from the production buildings dust in the air reliably reduced (at $P \leq 0.05 - 0.01$) compared to that in the buildings (P_1 and P_2), average for the studied period as follows:

– at points in the leeward of the farm: in P_3 at 2 m from the buildings – from 1.6 to 2.1 times; in point P_4 at 50 m - from 2.5 to 3.3 times;

– at the point of wind over side of the farm - P_5 at 10 m from the buildings - from 1.4 to 1.8 times.

Expressed by coefficient of technogenic (CT), calculated on the basis $MPC_{av.d.c.}$ - 0.25 $mg.m^{-3}$ and $MPC_{m.s.c.}$ - 0.50 $mg.m^{-3}$ (Regulation № 14/1997), the degree of air pollution in the investigated points around the farm buildings, on average for the period was as follows:

– at P_3 – CT = 5.0 on $MPC_{av.d.c.}$ and CT = 2.5 on $MPC_{m.s.c.}$;

– at P_4 – CT = 3.3 on $MPC_{av.d.c.}$ and CT = 1.6 on $MPC_{m.s.c.}$;

– at P_5 – CT = 5.9 on $MPC_{av.d.c.}$ and CT = 3.0 on $MPC_{m.s.c.}$.

As regards the requirements for ambient air quality in urban areas (Regulation № 14/1997) it was established that air at 50 m in the leeward of the farm did not qualify for the content of dust (TC > 1). The greatest deviations from the norms were in the P_5 and the lowest - in P_4.

Microorganisms. 1. Total count of cultivable microorganisms (TCCM). A. Emissions. The count of microorganisms in the air of the buildings ranged widely - from $89{,}0 \times 10^3$ to $428{,}0 \times 10^3$ CFU/m^{-3} air in the building for sows and litters (P_1) and from 13.0×10^3 to $120{,}0 \times 10^3$ CFU/m^{-3} air in the building for fattening pigs (P_2), (Table 3). In P_1 NCM was statistically greater (at $P \leq 0.01$) than in P_2 - from 2.4 times in autumn to 16.9 times in the summer, average for the period - 5.9 times. We assume that the main reason TCCM in P_1 to be bigger than in P_2 is related to the housing of these two categories of pigs. Farrowing sows all time in the year kept in closed building with controlled microclimate, where the air temperature and humidity were higher, than in the building for fattening pigs. These conditions favor the survival of microorganisms in the air. The fattening pigs kept in a building without heating and they had permanent access to yards for a walk. That's all allows for more intensive air ventilation, respectively, a sudden change in daily and seasonal temperature and humidity – factors, limiting the survival of microorganisms in the air at P_2. The obtained results demonstrated a direct correlation between the conditions of the microclimate in the buildings and the TCCM of the air. In this case the factor "conditions of the air environment in production building" has a greater impact on the TCCM of the air than the factor "building capacity", findings in other studies (Baykov, 1988). In seasons TCCM in the air of the two buildings was characterized by diverse developments. In building for sows and litters (P_1) TCCM was highest in summer and lowest in autumn, while in the building for fattening pigs (P_2) the highest values were in autumn and the lowest - in summer. Nevertheless, all differences in seasons and an average for the period were statistically proved at $P \leq 0.05$.

Animal hygiene assessment of the air in the buildings showed that the air quality meets the requirements of Regulation № 44/2006,

Table 3. Content of total dust and microorganisms in the air of the pig farm

Season	Points				
	P_1*	P_2	P_3	P_4	P_5
			Total dust, $mg.m^{-3}$ air		
Summer (n = 6)	a 2.62±0.77	A 1.37±0.42	Ab 1.58±0.23	c 0.90±0.08	Ad 1.94±0.15
Autumn (n = 6)	Ba 2.50±0.88	4.35±0.43	Bb 1.76±0.58	c 0.90±0.73	Bd 1.45±0.21
Winter (n = 6)	C 1.28±0.61	2.35±1.50	0.86±0.10	Cc 0.67±0.11	Cd 1.04±0.22
Av. for the period (n = 18)	D 2.03±0.82	D 2.69±0.73	1.40±0.20	0.82±0.17	D 1.48±0.16
Min	1.46	0.71	1.02	0.17	1.02
Max	4.98	5.11	3.63	2.54	2.18
Animal Hygiene Standard **	5.0	5.0	-	-	-
Working conditions Standard ***	5.0	5.0	-	-	-
Air quality Standard for the settlements ****	-	-	0.25 [I] 0.50 [II]	0.25 0.50	0.25 0.50
			Total count of cultivable microorganisms, (x 10^3 CFU/m^{-3} air)		
Summer (n = 6)	e 314.0±81.6	E 18.5±3.3	Eg 21.5 ± 6.2	Eh 14.5 ± 4.1	Ek 10.0 ± 2.4
Autumn (n = 6)	e 119.5 ± 4.6	Ff 49.5 ± 20.9	Fg 28.2 ± 9.3	Fh 20.5 ± 5.8	Fk 12.5 ± 5.2
Winter (n = 6)	e 122.3 ± 8.9	Gf 35.5 ± 12.1	G 11.7 ± 1.6	8.5 ± 3.1	Gk 13.0 ± 9.3
Av. for the period (n = 18)	198.1±43.0	H 33.5 ± 7.1	H 20.4 ± 3.7	H 14.5 ± 2.6	H 11.8 ± 2.6
Min	89.0	13.0	6.0	4.0	1.0
Max	428.0	120.0	50.0	37.0	22.0
Animal Hygiene Norm **	250.0	250.0	-	-	-
Working conditions Standard ***	15.0	15.0			
Air quality Standard for the settlements ****	-	-	0.75	0.75	0.75
			Number of Coliform Bacteria, (x 10^3 CFU/m^{-3} air)		
Summer (n = 6)	1.50	NP	0.25	0.25	NP
Autumn (n = 6)	1.83	NP	NP	0.83	0.50
Winter (n = 6)	1.67	NP	NP	NP	NP
Average for the period	1.17	NP	0.83	0.36	0.17
Min	NP	NP	NP	NP	NP
Max	5.50	NP	0.50	2.50	1.50

* The marks are the same as in Table 2

since all established values were within the acceptable norm for pigs – up to $250x10^3$ CFU/m^{-3} air. The exception was the monthly value in July in the building for sows and litters, which was higher than norm. In assessing air quality in terms of hygiene requirements for working conditionsq results showed that the TCCM exceeded MPC in the working environment (up to $15x10^3$ CFU/m^3 air by Danon-Moshe et al., 1985) – from 7.5 to 20.9 times in P_1, and from 1.01 to 2.3 times in P_2. According to this indicator air quality in buildings didn't meet the hygiene requirements for the working environment. It should be noted that the TCCM in the air in the working environment isn't yet legally regulated item. Enrichment of information on the issue will help justify the rule on this air quality indicator. Production buildings of pig farm were significant sources of emissions from saprophytic microorganisms - from 13.10^3 to 428.10^3 CFU/m^3 air.

B. Immissions. In control points outside of the farm buildings the content of microorganisms was highest at 2 m - P_3 (average for the period $20,4.10^3$ CFU/m^3 air) and the lowest at 10 m - P_5, respectively $11,8.10^3$ CFU/m^{-3} air. In point P_4, at 50 m from the leeward of the farm the TCCM in the air was with intermediate values (Table 3). In seasons TCCM showed divergent trends. At two points (P_3 and P_4) TCCM was smallest in winter, at two points (P_2 and P_5) - in summer, and in one point (P_1) - in autumn. Regarding the maximum values distribution was also different: at P_1 the maximum values were in summer, at P_2 and at P_3 -respectively, in the autumn and in P_5 - in the winter.

With increasing the distance from the farm TCCM drastically decreased compared to the production buildings (P_1 and P_2). Average for the period the redudcing was as follows: in P_3 - from 1.6 to 1.7 times; in P_4 - from 2.3 (proved at $P \leq 0.05$) to 33.7 times (proved at $P \leq 0.001$); in P_5 - from 2.8 (proved at $P \leq 0.05$) to 16.7 times (proved at $P \leq 0.001$). The results characterized TCCM of air as a highly volatile indicator, a fact which shows that the number of microorganisms in the air is influenced by many environmental factors, which are determined by meteorological factors. The sharp reduction in the count of microorganisms in the air with increasing the distance from the farm was determined by the deterioration of the environment in which microorganisms can not maintain his vital functions and die. Expressed by coefficient of technogenic (CT), calculated on the basis $MPC_{av.d.c.}$ - 750 CFU/m^{-3} air, the degree of air pollution in outside points of the farm, on average for the period was as follows: at P_3 CT = 27.2; at P_4 CT = 19.3 and at P_5 CT = 15.8. In all points the CT values were greater than one (CT > 1), therefore air quality didn't meet the requirements. This assessment should be taken with some conditionality, as not yet legally regulated norm. However, it was clear that production buildings of the farm are a major source of emissions of microorganisms that contaminate the air in the adjacent areas.

2. Number of Coliform Bacteria (NCfB). A. Emissions. Coliform bacteria evidenced in the air only in the building for sows and litters (P_1) during certain months (June, July, November and January) and their count has not exceeded $5,5.10^3$ CFU/m^{-3} air. In the air of the building for fattening pigs (P_2) throughout the trial was not proven coliform bacteria (Table 3). Although coliform bacterias were established in the air only in one of the two investigated buildings of the farm, it showed that pig production buildings are a potential source of emissions of these bacteria. The fact gives rise to control this indicator characterizing air quality in terms of availability of sanitary microorganisms in the air. The data confirm some earlier established unidirectional dependencies - on the one hand between the capacity of the production unit and the number of Coliform bacteria in the air and, secondly, between the TCCM and the NCfB in the air (Petkov and Baykov, 1988; Baykov, 2000; Petkov, 2006). NCfB in the air is not legally regulated indicator, but generally accepted (Petkov et al., 1978) that in the clean air in the buildings for animals should not be contain sanitary-indicative microorganisms to which group concerned and coliform bacteria.

B. Immissions. Coliform bacteria were established at all points around the farm – from 83 CFU/m^{-3} air at P_3 to 361 CFU/m^{-3} air at P_4 (Table 3). In seasons, the quantity of coliform bacteria at P_4 and P_5 was highest during autumn and lowest in winter, when not proven. In P_3 coliform bacteria observed only in the summer and during other two seasons (autumn and winter) absent. The NCfB in ambient air around the pig farm was highly volatile indicator, which gives reason to suppose that it is determined by the impact of many environmental factors. However, the presence of coliform bacteria in the air can be regarded as an indicator of its quality.

Conclusion

Air quality in the production buildings of the pig-farm meets the requirements for growing pigs on content of dust and microorganisms and significantly deviate from norms in terms of content of ammonia and hydrogen sulfide. As a factor in the working environment for staff at the farm, the air quality meets the requirements. This difference in regulations between the requirements for air quality for pigs and for staff in the farm, having to lift a discussion on the problem, justified on the new standards and their synchronization in the normative documents.

The buildings for sows and litters, and for fattening pigs were significant sources of emissions of ammonia (7.93 -15.82 mg.m^{-3} air), hydrogen sulfide (3.31 - 7.10 mg.m^{-3} air), total dust (0.71 - 5.11 mg.m^{-3} air), saprophytic microorganisms ($13.0x10^3$-$428.0x10^3$ CFU/m^{-3} air), coliforms bacteria (0-5500 CFU/m^{-3} air). In some cases differences in the emission of the investigated parameters between seasons on the buildings for different categories of pigs and between seasons for the same building were statistically proven at P < 0.05-0.001.

Emissions of ammonia, hydrogen sulfide, dust and microorganisms from the farm buildings maintain measurable concentrations of these pollutants, i.e. imission, at 50 m leeward and at 10 m over wind side position of the farm. With increasing the distance from the production buildings of the farm contents of ammonia, hydrogen sulfide, dust and microorganisms in the air decreased from 1.4 to 13.7 times at 50 m from the downwind side and from 1.4 to 16.7 times at 10 m from over wind side of the farm. However, air quality didn't meet the requirements for ammonia and dust content up to 50 m from the downwind side and to 10 m from over wind side of the farm. For the content of hydrogen sulfide that distance was even less - until 2 m from the leeward and until 10 m from the over wind side of the farm.

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Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices)

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods, Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

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Abstract should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

Keywords: Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

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Book chapter or conference proceedings: Author(s) surname and initials, year. Title. In: Title of the book or of the proceedings followed by the editor(s), volume, pages. Name of publisher, place of publication. Example:

Mauff G, Pulverer G, Operkuch W, Hummel K and Hidden C, 1995. C3-variants and diverse phenotypes of unconverted and converted C3. In: Provides of the Biological Fluids (ed. H. Peters), vol. 22, 143-165, Pergamon Press. Oxford, UK.

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Penkov D, 2008. Estimation of metabolic energy and true digestibility of amino acids of some feeds in experiments with muscus duck (Carina moshata, L). Thesis for DSc. Agrarian University, Plovdiv, 314 pp.

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