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PRELIMINARY STUDY OF DIETS EFFECTS ON PERFORMANCE, CO_2 EMISSION AND MICROCLIMATE VARIATION OF PRIMIPAROUS SOWS

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Abstract

At present, the widespread raising of swine in farms becomes a serious problem in terms of the emission of carbon dioxide (CO_2), having an environmental impact. The objective of this study was to investigate the effect of different diets on growth parameters changes in physical size, carbon dioxide (CO_2) emission and microclimate monitoring. For 28 days, 7 TOPIGS sows (average initial body weight, BW ~ 205.09 kg) were allotted in two dietary treatments: control (C diet, 1.6% soybean oil) and experimental (E diet), (with 1.6% hemp oil). The type of oil differed by their fatty acids (FA) composition. Sows were individually weighed, P2 backfat thickness was determined by ultrasound and morphometric measurements of body size were taken three times during lactation. The CO_2 emitted by sows and their litter was calculated. Microclimate parameters were recorded daily. The addition of 1.6% hemp oil in the diet improved sows final body weight and reduced weight loss ($P<0.05$). A high significant negative Pearson correlation was observed between PUFA intake, and their fraction (Σ n-3, Σ n-6, Linolenic and Linoleic as predominant n-3 and n-6 FA). The proportion of CO_2 exhalated by sows fed E diet was significantly lower compared to C diet. The CO_2 emission, temperature and relative humidity were affected ($P<0.001$) by the sows' physiological status. The results from this study are indicating that the hemp oil inclusion in the sow's diet has a beneficial effect on performance. Further studies are necessary to determine the nutrition impact on environmental conditions.

Key words: *carbon dioxide, morphometric measurements, performance, sows.*

INTRODUCTION

At present, continuing food-feed competition, land degradation and climate change represent significant sustainability challenges for the livestock industry. These changes have led to a progressive increase in the use of lower-cost co-products to replace partial maize and/or soybean meal, with emphasis on their role in swine diets (Wachenheim et al., 2006). The oils are one of the main alternatives argued by their functional property, for example, soybean oil and hemp seed oil.
As is well known, the most commonly used oil in the diet of sows is soybean oil, a valuable source of n-6 fatty acids. Hemp seed oil, compared to soybean oil is an ideal by-product rich in n-3 fatty acids, with an important function in development, health and immunity.
However, in the literature, studies regarding utilization of hemp seed oil respectively hemp seed in feeding the sows are limited (Habeanu et al., 2018). Recent studies (Doreau et al., 2013; Habeanu et al., 2019; Habeanu et al., 2020) revealed that oil-rich ingredients used in pigs' diet could have a positive effect of reducing greenhouse gas emissions.
Over the past few years, environmental and welfare concerns in the livestock industry have increased. In the swine industry, air quality has become a sensitive subject these days, and have started to attract researcher attentions. Although various microclimate installations are currently on the market and are being promoted, indoor air quality is still a challenge to farmers.
Poor indoor air quality can have an impact on swine health, productivity and well-being, besides being a health risk to farm workers.

Furthermore, studies have revealed that poor indoor air quality is often associated with respiratory diseases, stress and decreased pig productivity. (Cleveland-Nielsen et al., 2002; Michiels et al., 2015; Roque et al., 2018).

Livestock production is one of the most important sources of greenhouse gases emissions (Dong et al., 2009). The most fixed gases registered in swine facilities is carbon dioxide (CO2) which play a major role in indoor air quality measurements. The two major sources of CO2 production in pig housing are animal respiration and manure release (Habeanu et al., 2020).

The objectives of this paper consist in: i) assess the effect of dietary hemp seed oil relative to soybean oil in lactating sows' diets on performances; ii) evaluate the CO_2 emitted by sows and their piglets; iii) measuring of changes of indoor microclimatic parameters measurements.

MATERIALS AND METHODS

The present experiment was conducted at the experimental farm of INCDBNA Balotesti, according to Law 43/2014/Romania. All the experimental procedures were approved by the Ethical Committee (Protocol no. 699/2020).

Animals and Diets

A total of 7 TOPIGS primiparous hybrid sows were tested in this biological trial.

On day 105 of gestation, sows were moved to a farrowing room and kept in individual farrowing crates. Immediately after farrowing, the sows were divided into 2 experimental groups (Table 1), and feed with different diets: control (C; 1.6% soybean oil) and experimental (E; 1.6% hemp oil). The variable was the type of oils with different fatty acids (FA) composition summarized in Table 2.

Table 1. Ingredients and nutrient composition of sows' diet during gestation and lactation

Ingredients, %	**Lactation**	
	C	**E**
Corn	56.87	56.87
Rice meal	10.00	10.00
Soybean meal	18.00	18.00
Sunflower meal	10.00	10.00
Soybean oil	1.60	-
Hemp oil	-	1.60
Lysine	0.02	0.02
Calcium carbonate	1.75	1.75
Monocalcium phosphate	0.15	0.15
Salt	0.40	0.40
Choline premix	0.20	0.20
Vitamin-mineral premix P5+6	1.00	1.00
Phytase	0.01	0.01
Calculated chemichal composition, %		
DM	89.71	89.70
Metabolisable energy (MJ/kg)	3070	3070
Crude protein	17.97	17.42
Lysine	0.87	0.87
Digestible Lysine	0.69	0.69
Methionine + Cystine	0.65	0.65
Digestible Methionine + Cystine	0.52	0.52
Calcium	0.92	0.93
Phosphorus	0.80	0.81
Crude fiber	5.59	5.91
Crude fat	5.62	5.24

ME and amino acid contents were calculated based on feed composition. Gestation diets were provided in one meal/day; lactation diets were provided in two meals/day.

Vitamin mineral premix P5 + 6: 9000 IU vitamin A; 1500 IU vitamin D3; 50 IU vitamin E; 2 mg vitamin K3; 1.5 mg vitamin B1; 5.2 mg vitamin B2; 15 mg vitamin B3; 8.1 mg vitamin B5; 2 mg vitamin B6; 0.10 mg vitamin B7; 0.5 mg vitamin B9; 0.03 mg vitamin B12; 39 mg of Mn; 100 mg of Fe; 15 mg Cu; 100 mg Zn; 0.3 mg I; 0.22 mg Se; 0.25 mg Co; 60 mg antioxidant.

The experimental diet contained a higher amount (>3.42 times) of Σ n-3 FA and a ratio of 3.53 times greater in E diet n-6: n-3. Throughout the entire experimental period, sows had *ad libitum* access to feed and leftovers were registered daily. The sows had free access to the water both in the individual pens.

Table 2. Fatty acids profile of soybean oil, hemp seed oil and diets used during the experiment

Fatty acids, % of total FAME	Oils		Diet	
	Soybean oil	Hemp seed oil	C	E
Σ SAF	14.95	12.86	15.76	16.66
Σ MUFA	27.22	14.59	33.05	29.86
Σ PUFA	57.75	72.58	51.18	53.46
Σ n-3	6.58	17.30	1.54	5.27
Linolenic	6.68	17.06	1.03	5.07
Σ n-6	52.29	53.79	49.64	48.19
Linoleic	51.11	55.28	49.60	48.12
n-6/n-3 ratio	7.77	3.20	32.23	9.14

SFA - saturated FA; PUFA - polyunsaturated FA; MUFA - monounsaturated FA.
Total SFA: C8:0 + C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C24:0; Total MUFA: C15:1 + C16:1 + 17:1 + Total trans 18:1+ C18:1 cis-9 + C18:1 cis 7 + C20:1n-9 + C22:1n-9 + C24:1n-9; Total PUFA: C18:2n-6 + C18:3n-6 + C18:3n-3 + C18:4 n-3 + CLA + C20:52n-6 + C20:3n-3 + C20:4n-6 + C22:2n-6 + C20:5n-3 + C22:3n-6 + C22: 3n-3 + C22:4 n-6 + C22:5 n-3 + C22:6n-3.

Measurements

All measurements of sows (body weight (BW), backfat, morphometric) were made after farrowing and at weaning.

Sows backfat thickness (mm), lean meat thicknesses (mm) and loin muscle percentage (%) was measured between 3rd and 4th lumbar vertebra at 7 cm, laterally (P2 position), from the backline using a PIGLOG 105 (SFK Technology, Denmark) ultrasound scanner. The final result for backfat thickness was the average value from both sides of P2 position measurements. Before measurements age (days) and live weight (kg) of sows were introduced into the device.

The morphometric measurements of the sows (heart girth, length and flank) were made by using a cloth tape measure. Heart girth is defined as the circumference of the sow just behind the forelegs and shoulders and in front of the first mammary gland, while flank-to-flank is taken from the bottom of the left flank to the bottom of the right flank, running over the top of the sow. The morphometric and backfat measurements of sows were taken when the sows were upright and relaxed.

Indoor microclimatic measurements such as carbon dioxide (CO_2), relative humidity (% rH), atmospheric pressure (hPa), air temperature (°C) and room airflow speed were continuously measured during the lactation phase at 8:00, 10:00 and 14:00 hours with a portable digital instrument Testo. As a final result, the average of the three measurements was taken into consideration.

Chemical composition

Samples from C and E diets were taken at the beginning of the experiment and were chemically analysed for weende by standardised methods (Commission Regulation (EC) no. 152, 2009) and fatty acids.

Fatty acids. The fatty acids profile was determined by gas chromatography (Perkin Elmer Clarus 500 gas chromatograph, Massachusetts, United States), fitted with flame-ionization detector (260°C temperature) and capillary separation column with high polar stationary phase Agilent J & WGC Columns, (United States), DB-23 dimensions 60 m x 0.250 mm x 0.25 µm. The FA were identified by comparison with blank chromatograms and were subsequently determined quantitatively as a percent of total FAME. SUPELCO 37 component FAME Mix was used; 10 mg/ml as a standard solution of methylated FAs and also Soybean Oil and Sunflower Oil; SUPELCO, as reference material was used. We used hydrogen as carrier gas and oxygen as burning gas, (method described by Hăbeanu et al., 2016). The mean values for FA composition were presented as g FA/100 g total FA ester methyl (%), and g/kg diet.

Statistical analysis

The data were submitted to variance analysis using the General Linear Model (GLM) of the SPSS program (SPPS, 2011). The results were expressed as mean values and standard error of the mean (SEM). To evaluate the relationship between certain parameters, Pearson's correlation was used. Differences were considered significant if $P<0.05$, and highly significant when $P<0.001$.

CO_2 emitted was calculated from the heat production (HP, MJ/day, corrected for density (22.4 l/mol) and molar weight (44 g/mol) using the formula described by Rigolot et al. (2010)

and Noblet (1987) adapted by Habeanu et al. (2020) adapted for sows and piglets.

RESULTS AND DISCUSSIONS

Growth parameters

As known sows' diet supplementation with oils during lactation has been shown to improve milk composition as well as piglet's performance. However, studies of the benefits of hemp seed oil inclusion in lactating sows diets, on body performances it is limited.

In order to prevent the excessive gain of body condition the average feed intake during gestation was limited to 2.80 kg/d.

During lactation, the sows fed C diet registered an average feed intake of 5.82 kg/d while the E group consumed an average feed intake of 6.09 kg/d, without significant differences between groups.

Table 3. Means of feed, calculated fatty acids intake and performance

Item**	C	E	SEM	P-value*
Feed intake kg/d	5.82	6.09	0.07	*0.108*
Fatty acids intake g/kg feed				
Σ SAF	41.90	41.94	0.59	*0.973*
Σ MUFA	65.92	57.27	0.93	*0.0001*
Σ PUFA	125.88	145.69	2.04	*0.0001*
Σ n-3	8.93	19.35	0.41	*0.0001*
Linolenic	8.99	19.10	0.40	*0.001*
Σ n-6	117.49	125.86	1.75	*0.018*
Linoleic	116.22	124.24	1.73	*0.021*
n-6/n-3 ratio	61.50	59.99	0.86	*0.388*
Growth parameters				
Sows BW -12 h after farrowing	203.00	205.50	0.79	*0.102*
Sows BW -Weaning (28d)	176.67	186.25	1.12	*0.0001*
Total body weight loss	*-26.33*	*-19.25*	*1.16*	*0.001*
Total no. of piglets borne alive, head	14.67	10.50	1.51	*0.139*
Piglets BW, kg	1.30	1.62	0.09	*0.001*
ADG, g	237.19	247.79	1.72	*0.002*
No dead piglets	1.00	0.5	0.36	*0.542*

[1]C: control group; [2]E: experimental group; [3]SEM: standard error of the mean.
*P < 0.001 highly significant difference; P < 0.05 significant difference; P < 0.10 tendency of influence; P > 0.10 not significant.
SFA - saturated FA; PUFA - polyunsaturated FA; MUFA - monounsaturated FA.
Total SFA: C8:0 + C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C24:0; Total MUFA: C15:1 + C16:1 + 17:1 + Total trans 18:1 + C18:1cis-9 + C18:1 cis 7 + C20:1n-9 + C22:1n-9 + C24:1n-9; Total PUFA: C18:2n-6 + C18:3n-6 + C18:3n-3 + C18:4 n-3 + CLA + C20:2n-6 + C20:3n-3 + C20:4n-6 + C22:2n-6 + C20:5n-3 + C22:3n-6 +C22:3n-3 + C22:4n-6 + C22:5n-3 + C22:6n-3.

The average of estimated FA intake (Table 3) differed (P=0.0001) between diets. Thus, sows fed E diet ingested a lower amount of monounsaturated FA (<13.12%; MUFA) and a higher amount of polyunsaturated FA (>15.74%; PUFA), n-3 (>53.85%), respectively n-6 (>7.12%) compared with sows fed C diet.

The average BW loss at weaning was lower (<5.42%; P = 0.0001) in the sows fed E diet compared with sows fed C diet. The total weight loss of sows, from farrowing to weaning were significantly affected, Contrary to our results Vodolazska and Lauridsen (2020) observed that sows' BW ranging from 320 ± 10.8 kg (hemp seed oil diet) to 346 ± 11.4 kg (soy-bean oil diet). Lows et al. (2018) that diet supplementation with palm oil has not affected sow performance.

According to Lawlor and Lynch (2007), Cozzanet et al. (2018) and Habeanu et al. (2018) sows body weight loss during lactation occurs as a result of high milk yield and a relatively small appetite. Different authors suggest that sows can lose between 15-40 kg of body weight during lactation (Hansen, 2013; Cools et al., 2014).

The main effects of diet and period on sows' body measurements are outlined in Table 4.

Lactating sows feed E diet had a backfat thickness lower 25.88% (P = 0.011) compared to lactating sows fed C diet while lean meat registered a value 7.25% higher (P = 0.009);

compared to a similar backfat thickness evolution on lactating sows has been noticed also by Eissen et al. (2003). However, Lavery et al (2019) using salmon oil, mentioned that sow body condition was not improved and back-fat depth in his study decreased as lactation progress, not as dietary treatment.

Table 4. Effect of hemp oil on sows' body measurements during lactation

Diets	Period	Backfat thickness (mm)	Loin eye (mm)	Lean Meat (%)	Heart grind	Flank	Length
C	AF	18.33	44.67	52.07	133.67	148.67	133.00
	d-5	17.50	41.00	52.33	135.67	147.67	136.33
	d-21	14.17	40.33	55.50	126.67	141.67	127.00
	d-28	11.67	42.00	58.03	125.33	134.33	132.67
E	AF	13.25	43.25	56.80	133.25	147.50	137.75
	d-5	14.75	49.25	56.05	131.75	144.75	136.25
	d-21	10.50	43.50	59.33	128.00	141.00	135.75
	d-28	10.50	43.75	59.38	125.75	128.75	137.50
SEM		0.71	1.03	0.71	1.10	1.87	1.59
Main effects							
Diet							
C		15.42	44.36	55.01	131.11	140.28	132.00
E		12.25	47.83	58.09	130.08	137.04	135.17
Period							
	AF	15.79	43.96	54.43	133.46	148.08	135.38
	d-5	16.13	45.13	54.19	133.71	146.21	136.29
	d-21	12.33	41.92	57.41	127.33	141.33	131.38
	d-28	11.08	42.88	58.70	125.54	164.21	135.08
P-value							
Diet		*0.011*	*0.181*	*0.009*	*0.749*	*0.425*	*0.198*
Period		*0.010*	*0.737*	*0.033*	*0.015*	*0.007*	*0.755*
Diet*Period		*0.670*	*0.458*	*0.773*	*0.803*	*0.946*	*0.841*

C: control group, [2]E: experimental group. AF: after farrowing; d-5: day 5; d-21: day 21; d-28: day 28
SEM: standard error of the mean.
*P < 0.001 highly significant difference; P < 0.05 significant difference; P < 0.10 tendency of influence; P > 0.10 not significant.

During the experimental period, the significant difference was noticed for all parameters evaluated. Although 5d AF the backfat thickness increased slightly (2.15%), up to 28d the backfat thickness decreased 29.8% (P<0.01), respectively. A contrary tendency was observed with respect to lean meat which registered a higher value at 28d AF compared to first d (7.8%, P<0.033). A backfat reduction in sows, AF was also observed by Eissen et al. (2003), Cozzanet et al. (2018) and Lavery et al (2019). According to Song et al. (2010) and the authors mentioned above, lactating sows use more energy for milk production which automatically leads to a reduced backfat, body weight losses or other negative productive performances.

The sampling time had a significant effect on heart grind and flank measurements (P = 0.015 respective P = 0.07).

There was no interaction found between diet and period for any of the body measurements determined on sows.

CO_2 emitted and microclimatic condition

The indoor animal husbandry environments are one of the most important in the swine sector because have a direct impact on production efficiency respectively animal health and welfare. As well-known carbon dioxide is the second most important greenhouses gas emissions that can be generated during the production due to the heating, ventilation, feeding, manure handling, and washing (Hörndahl, 2008, MacLeod et al., 2013 Boontiam et al., 2015).

The calculated sows' and their litter CO_2 emissions and the registered mean values of the microclimate in the sows' farrowing unit are presented in Table 5.

In HP calculation was used EN and EM intake. In our study EN and EM intake was similar between diets and did not differ significant.

Our data revealed that the proportion of CO_2 exhalated by sows fed E diet was significantly lower, which can be attributed to the fact that HP value was also decreased compared to C diet. A possible explanation can be attributed to the highly significant negative correlation between PUFA, especially n-3 FA in which linolenic FA is predominant and CO_2 emitted by animal's respiration.

Table 5. Heat production and CO_2 exhalation from sows and piglets

Item	C	E	SEM	P-value
Sows				
EN intake	50.14	52.52	0.73	*0.108*
EM intake	67.28	70.48	0.98	*0.108*
HP (MJ/day)	21.29	20.51	0.10	*0.0001*
CO_2 emitted (kg/d)	1893.34	1823.74	9.16	*0.0001*
Piglets				
HP (kcal/day)	433.27	449.60	2.66	*0.002*
CO_2 emitted (kg/d)	37.99	39.43	0.23	*0.002*
TOTAL CO_2 Emitted kg/d	1931.33	1863.17	9.12	*0.0001*

C: control group; E: experimental group; EN: net energy; EM: metabolizable energy; HP: heat production;
SEM: standard error of the mean.
$P < 0.001$ highly significant difference; $P < 0.05$ significant difference; $P < 0.10$ tendency of influence; $P > 0.10$ not significant.

Regarding the CO_2 emitted by piglets we observed that piglets from sows fed E diet registered a higher HP and CO_2 production compared to C diet (> 3.79%, P = 0.002). This was expected since there is a strong correlation between CO_2 production and body weight (r = 0.83). Thus, animal growth necessitate energy, which automatically will lead to an increase CO_2 production.

According to Forcada and Abecia (2018) and CIGR (2002) the estimated production of respiratory CO_2, on the basis of body weight and feed energy intake, is 2.23-3.68 kg CO_2 per head for gestating and lactating sows respect-tively 0.88 kg CO_2 per head for weaned piglets.

The correlation between dietary FA and pro-duction CO_2 from sows and piglets is presented in Table 6. As can be observed all correlation were negatively between CO_2 and FA.

As presented in Table 7, we can observe that the amount of CO_2 emissions registered in the farrowing unite it is relative higher. Part of the CO_2 concentration is from animal respiration and part of the manure.

Compared to our values, Stinn et al. (2014) recorded higher CO_2 concentration 1556 (± 783) ppm, 1631 (± 811) ppm, and 1594 (± 797) ppm for the farrowing room, and mentioned that only CO_2 continued to increase, with the age of piglets while N_2O and CH_4 remained unchanged.

Table 6. Pearson corelation between calculated CO_2 emissions and fatty acid intake

Items	CO_2 emitted			
	Sows		Piglets	
	r	P	r	P
Σ SAF	-0.40**	*0.0001*	0.03	*0.636*
Σ MUFA	-0.29**	*0.0001*	-0.04**	*0.616*
Σ PUFA	-0.47**	*0.0001*	0.10	*0.155*
Σ n-3	-0.43**	*0.0001*	0.19	*0.005*
Linolenic	-0.43**	*0.0001*	0.19**	*0.006*
Σ n-6	-0.44**	*0.0001*	0.07	*0.345*
Linoleic	-0.44**	*0.0001*	0.06	*0.352*
n-6/n-3 ratio	-0.39**	*0.0001*	0.2	*0.772*

**Corelation is significant at the 0.01 level (2-taild); * Corelation is significant at the 0.05 level (2-taild)

Table 7. Physical microclimatic parameters in the farrowing unit

Items	MEAN	Minimum/ maximum	SD
CO^2 (ppm)	1264.7	798.8/3952.7	102.5
hPA	1004.03	986.5/1016.4	0.82
Temperature (°C)	24.6	21.9/25.5	0.1
Relative humidity (%)	65.4	44/99.9	1.64
Airflow velocity (m/s)	0.1	0.0/0.28	0.01

According to Philippe and Nicks (2014), farrowing sows, including piglets are associated with the highest CO_2 emissions, as a consequence of *ad libitum* feeding and intensive productive status (milk production and growth). Another cause for the increased CO_2, can be attributed to the temperature. There are several studies (Groenestein et al., 2003; Moehn et al., 2004; Philippe and Nicks, 2014) demonstrating that the level of CO_2 emission doubled when temperature increased from 15 to 20°C.

As a result of extensive temperature, ventilation and animal activity effects, same authors (Groenestein et al., 2003; Moehn et al., 2004;

Philippe and Nicks, 2014) observed a diurnal pattern of gassed emissions from pig houses. Thus, the highest gas emissions were registered during feeding time.

The registered mean values of temperature were of 24.6°C. An increase of temperature values was expected during lactation period, because the lower critical temperature for piglets in the first days of life is around 33°C (Bloemhofet al., 2008).

The relative humidity values recorded in our study are in agreement with values obtained by Romanini et al. (2008) and Justino et al. (2014) that registered a relative humidity of 75% respective 69.8%. According to Justino et al. (2014), the relative humidity optimum value for pigs is between 60 to 80%. Regarding the atmospheric pressure and the air flow velocity, this were within recommended parameters.

CONCLUSIONS

The addition of hemp seed oil in the sows lactating diet had a beneficial result and have proven to minimise weight loss after farrowing. A high significant negative Pearson correlation was observed between PUFA intake, and their fraction (Σ n-3, Σ n-6, Linolenic and Linoleic as predominant n-3 and n-6 FA). The indoor microclimate from farrowing unit was within the normal parameters and did not affect the lactating sows.

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