Influences of different sources and levels of crude fiber on performances, fatty acids profile and carcass traits in growing-fattening pigs' diet

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ABSTRACT

The present study has investigated the potential of including different sources and levels of fiber (6.5% and 7.5%) in growing-fattening pigs' diet. The nine weeks feeding trial was conducted on nine hybrids TOPIGS castrated males with an initial average weight of 25.25 ± 2.11 kg, randomly assigned to 3 experimental groups with 3 replicates per group.

The control group (C) was fed with a corn, wheat and soybean basal diet and it was characterized by 3.5% crude fiber (CF), the experimental groups E1 had 6.5% CF (4% alfalfa meal and 12.36 % sunflower meal) and E2 had 7.5% (6% alfalfa and 18.38% sunflower meal) decreasing the dietary rate inclusion of soybean meal from C (21.42% soybean meal). Bodyweight (initial, final), average daily feed intake (ADFI), leftovers were registered and average daily gain (ADG), feed conversion ratio (FCR) were calculated during the experiment. At the end of the study, the pigs were slaughtered for the determination of carcass traits and meat quality parameters. The productive performances were not influenced by the source or level of the fiber content. The saturated fatty acid (SFA) values were significantly different ($P < 0.05$) in E1 group for shoulder and belly samples compared to C and for breast samples on E2. Higher MUFA concentrations significantly different ($P < 0.05$) were noticed for ham, sirloin, rack, shoulder, breast on E1. PUFA, $\Omega:6$ concentration shown significant differences ($P < 0.05$) within E2 to all meat samples collected, except the neck.

The best carcass classification results were recorded in the E1 with 6.5% cellulose (50% Class S and 50% Class E) according to the SEUROP system classification.

The study concluded that the dietary percentages of alfalfa meal and sunflower meal did not compromise productive performances but the average muscle thickness and meat percentage registered lower values compared with

group C. Further studies with the same raw materials but changing the inclusion percentages should have experimented with emphasis on carcass traits results.

Keywords: pigs; alfalfa; sunflower meal, productive parameters, carcass

INTRODUCTION

Today's trend in animal nutrition is to supplement or substitute the expensive sources of plant based-diet with inexpensive but, nonetheless, qualitative ones. Although corn-soybean meal diets are the best-balanced pig diets, regarding the energy and amino acids content, the increasing feed costs and economically competitive human consumption of the same ingredients led to the emergence of a niche by inclusion of alternative feed ingredients in pigs' diet.

There are some beneficial influences regarding the dietary fiber utilization in monogastrics concerning nutrient utilization and energy metabolism, but the negative effects on performances cannot be neglected (Agyekum, 2017).

According to Jarrett and Ashworth (2018) fibre digestion has beneficial effects on the function and the structure of the intestine due to the production of dietary fibre and short chain fatty acids. Therefore, in pigs these changes include villus height and crypt depth (Liang *et al.*, 2014) and a greater capacity of the intestine for oxidative metabolism (Weber and Kerr, 2012).

Kiarie and Nyachoti (2009) state that there are many existing, and some new, alternative ingredients that can be used in swine rations but is essential to understand their nutritive value, risks associated with using them (e.g., mycotoxins, anti-nutritional factors) and potential economic benefits when formulated correctly into pig diets.

According to Putnaff and Orloff (2014), alfalfa (*Medicago Sativa. L*) is the most important forage legume in the world because of its high adaptation, high yield and high quality. Alfalfa dietary fiber is mainly composed of cellulose, xylans and lignin (insoluble fiber) which represents approximately 90% of the total dietary fiber content of alfalfa (Chen L., *et al.*, 2013).

Eklung *et al.* (2014) published a study about the standardised ileal digestibility (SID) of amino acids in alfalfa meal, sugar beet pulp and wheat bran compared to wheat and protein ingredients for growing pigs, and concluded that SID values may improve diet formulation when these feed ingredients are used in diet formulation for pigs.

Protein and crude fiber are the main compounds in sunflower meal. Currently, the main current use of this protein by-product is in animal feed (Pedroche, 2015).

Sunflower meal (SFM), an oil industry by-product, represents a good source of protein with amino acid availabilities similar to those of soybean

meal, a major feed ingredient for monogastrics in many countries not suitable for extensive soybean cultivation. Sunflower meal could be included up to 16% in pigs' diet with no major effects on growth performance or carcass traits of finishing pigs (Carellos *et al.*, 2005).

The purpose of this study was to find out the effects of different sources and levels of dietary fiber (using feed alternatives as alfalfa and sunflower meal) on pigs' production performances and on fatty acid profile of the meat during growing-fattening phase

MATERIALS AND PROCESSES

The survey was carried out in compliance with Directive 2010/63/EU, Romanian law no. 43/11.04.2014, Executive Order No. 28/31.08.2011 and endorsed by the Ethics Committee of the National Institute for Research and Development for Animal Biology and Nutrition, Balotesti, Romania. All animals were healthy and did not receive antibiotics during the entire testing period.

Animals, treatments, samples collection

The experiment has been carried out for nine weeks (first week for accommodation), on 9 hybrid Topigs castrated males [♀ Large White×Hybrid (Large White×Pietrain)×♂Talent, (mainly Duroc)], with an initial average weight of 25.25 ± 2.11 . The individual metabolic cages (1.2×1.5×1 m) provided free acces to water nipples and feeders. The experimental conditions were similar for all groups: light – 8 hours a day, with a minimum intensity 40 lx; temperature $24^\circ \pm 2^\circ\text{C}$; relative humidity 70%. During the experiment pigs were weighed individually at the beginning and at the end of the experiment. Feed was given *ad libitum* twice a day. Feed consumption and leftovers were recorded daily per pig. The average daily gain (ADG), the average daily feed intake (ADFI), and feed conversion ratio (FCR) were calculated. The control group (C) was fed with a basal diet (corn and wheat) and included soybean meal (21.42%) exclusive; on experimental groups the soybean meal was decreased and added 4% alfalfa meal; 12.36 sunflower meal for E1 group and 6% alfalfa meal and 18.38% sunflower meal for E2, respectively (table 1).

The content of fiber in analyzed alfalfa meal samples was 23.96% CF and 21.18 % CF for sunflower meal samples, respectively.

At the end of the study, the pigs were weighted, transported to a slaughter house where, immediately after the slaughtering (high voltage head-to-back electrical stunning), meat samples (ham, sirloin, rack, neck, shoulder, breast, belly) were collected for fatty acids determination and the obtained carcasses were classified by the SEUROP method.

Table 1. Diet composition and calculated nutrient content

<i>Ingredients (%)</i>	Growing - fattening phase*		
	C diet	E ₁ diet	E ₂ diet
Corn meal	40.00	40.00	40.36
Wheat	34.36	24.34	19.29
Soybean meal (46%)	21.42	13.11	8.87
Alfalfa meal¹	-	4	6
Sunflower meal² (34%)	-	12.36	18.38
Sunflower oil	-	2.35	3.30
Lysine	0.35	0.50	0.58
DL-Methionine	0.12	0.12	0.12
Calcium carbonate (36%)	1.52	1.05	0.96
Monocalcium phosphate	0.84	0.78	0.75
Salt	0.39	0.39	0.39
Premix**	1.00	1.00	1.00
TOTAL	100.00	100.00	100.00
<i>Calculated nutrient content</i>			
DM(%)	86.57	83.61	82.10
ME(kcal/kg)	3232.18	3200.00	3200.00
Crude protein	17.50	17.50	17.50
Crude fat	1.84	4.01	4.88
Crude fibre	3.50	6.50	7.50
Calcium	0.80	0.70	0.70
Phosphorus total	0.54	0.58	0.59
Available phosphorus	0.35	0.35	0.35
Sodium	0.18	0.18	0.18
Chlorine	0.38	-	-
Lysine	1.10	1.10	1.10
Methionine	0.39	0.42	0.43
Met+Cis	0.71	0.71	0.71
Threonine	0.63	0.57	0.54
Triptofan	0.19	0.20	0.19
Arginine	1.02	0.98	0.95
Ac. Linoleic (C18:2)	1.17	2.41	2.91
ME/CP ratio	184.70	182.86	182.86

*weights ranged: 25.25 kg 9 ±2.11 (growing phase) to 80 kg±4.8 (fattening phase)

**Mineral-vitamin premix (1%) supplied per kg diet as follows: 10000 IU vitamin A, 2000 IU vitamin D₃, 30 IU vitamin E, 3 mg vitamin K₃, 2 mg vitamin B₁, 6 mg vitamin B₂, 13.5 mg d-pantothenic acid, 20 mg nicotinic, 3 mg vitamin B₆, 0.06 mg vitamin B₇, 0.8 mg vitamin B₉, 0.05 mg vitamin B₁₂, 10 mg vitamin C, 30 mg vitamin Mn, 110 mg Fe, 25 mg Cu, 100 mg Zn, 0.38 mg I, 0.36 mg Se, 0.3 mg Co, 60 mg antioxidant

Proximate composition analyses

The feed ingredients and compound feeds analyses were analyzed using the laboratory standard methods: ISO 6496:2001 was the method used for dry matter determination, ISO 5983-2:2009 was the method used for protein determination (Kjeltec 2300, Tecator, Sweden), SR ISO 6492:2001 was the method used for crude fat extraction (Soxtec 2055, Tecator, Sweden), ISO 6865:2002 was used for crude fiber analyses (Fibertec 2010, Tecator, Sweden) and ISO 2171:2010 was used for ash determination (Caloris CL 1206 oven, Romania).

Fatty acids analyses

Fatty acids content of the samples was determined using ISO/TS 17764-2 (2008) method (fatty acid methyl ester (FAME)/gas chromatography). Fatty acids from total lipid extracts were transformed into their methyl esters by transesterification in methanol containing 3% sulfuric acid concentrate at 80°C for 4 hours. Chromatograph Perkin Elmer-Clarus 500 with flame ionization detector (FID) and capillary column BPX70 (60m x 0.25mm i.d., 0.25µm film thickness) was used to analyze Methyl esters of fatty acids. The temperature of the column was set up at 5°C min⁻¹ from 180°C to 22°C. The carrier gas was hydrogen (35 cm s⁻¹ linear velocity at 180 °C) and the splitting ratio was 1:100. The injector and detector temperatures were 250 and 260°C, respectively. Identification of FAME was realized comparing with the retention times of the acknowledged standards. FAME content was expressed as weight percentage of total FAME present.

Meat sample collection and carcass classification

At the end of the experiment the pigs were slaughtered, according to Directive no. 93/113 C.E. and A.N.S.V.S.A Decree no. 180/2006), meat samples of ham, sirloin, rack, neck, shoulder, breast and belly (300-350 g) were immediately collected after the slaughter to establish the chemical composition and the fatty acid profile.

The carcass classification was done in Romania since 01 March 2006 using an OptiGrade-Pro (OGP) device (series A7509) by objective methods for assessing the lean meat content in the carcass. The device is equipped with an optical probe with a diameter of 6 mm, an infrared-sensitive photodiode (Siemens) and a phototransistor (Siemens). The operating margin is between 0 and 110 mm. The lean meat content of the carcass is calculated according to the following formula:

$$Y = 61.21920 - 0.767665 \times X_1 + 0.15239 \times X_2,$$

where:

Y = lean meat estimated percentage in the carcass;

X_1 = bacon thickness (mm), measured at 7 cm from the midline, between the third and fourth last rib;

X_2 = muscle thickness (mm), measured at 7 cm from the midline, between the third and fourth last rib.

The formula is applying for carcasses weighing between 50 and 120 kg. Using a computer, the results of the measurements are converted into estimated lean meat content.

Statistical analysis

Using STATVIEW for Windows (SAS, version 6.0), all the analytical data were compared performing analysis of variance (ANOVA). Differences between the average values in the groups were determined to be significant at $P < 0.05$.

RESULTS AND DISCUSSION

At the beginning of this study, samples of feed compound were analyzed for cellulose, NDF and ADF concentration for all experimental groups.

Figure 1. The cellulose, NDF, ADF values of experimental groups

Figure 1 shows a proportional increase in cellulose, NDF and ADF concentrations in relation to the dietary alfalfa and sunflower inclusion.

Chan et al. (2013) tried different levels of alfalfa dietary inclusion on growing pigs' (5%, 10%, 20%) and wheat bran (5%). A corn-soybean meal based diet containing 5% alfalfa inclusion+5% wheat bran it has provided 13.4% NDF and 10.1% ADF, whereas 10% alfalfa+5% wheat bran inclusion provided 15.6% NDF and 12.2% ADF.

Carellos et al. (2004) experienced five diets with increasing levels of SFM inclusion (0, 4, 8, 12 and 16%) on growth and carcass traits of finishing pigs. The corn-soybean meal diet based, with 12% dietary SFM inclusion provided

15.18 % NDF and 7.40% ADF, whereas 16% dietary SFM inclusion provided 16.31 % NDF and 8.47% ADF.

According to Haak et al., 2008, it is very common for pig producers to add linseed, sunflower, soybean or other sources of fatty acids into the finisher diet of pigs,

Fatty acids of the n-3 series are common especially in soybeans, while n-6 fatty acids are found in oilseed plants, seeds and nuts. Many pig producers include soy, sunflower, linseed or other oilseeds that contain n-3 and n-6 fatty acids, in swine finisher diet, to enhance the fatty acid composition of meat and fats.

Table 2 presents a higher concentration in PUFAs Ω :3 for the soybean meal compared to sunflower meal who registered higher concentration in PUFAs Ω :6.

The values were similar with those found by Antunović et al. (2019) who analysed samples of soybean meal for fatty acids composition (PUFA 53.40, MUFA 26.76, UFA 80.17, SFA 19.83) and samples of sunflower cake (PUFA 48.46, MUFA 30.26, UFA 78.72, SFA 21.28).

Table 2. Fatty acids profile (g/100g DM) determined in soybean meal and sunflower meal samples

Specification	Soybean meal	Sunflower meal
SFAs	20.36	17.62
MUFAs	23.22	29.89
UFAs	79.64	82.38
Total PUFAs	56.42	52.49
PUFAs Ω:3	6.62	1.53
PUFAs Ω:6	49.80	50.96
Ω:6/ Ω:3	7.52	33.31

SFAs - saturated fatty acids; MUFAs - monounsaturated fatty acids; PUFAs-polyunsaturated fatty acids.

Within table 3 it can be noticed that the different sources and levels of fiber dietary inclusion had no effect ($P>0.05$) on ADFI, ADWG, FCR parameters during the growing and fattening phase.

Nonetheless, the ADFI parameter of fattening phase of E1 group was slightly higher compared to group C and E2 and is correlated with the highest conversion feed ratio among the groups.

A soybean free experiment (sunflower meal, corn gluten feed, faba beans, dehydrated alfalfa meal and potato protein) carried out by Attilo et al. (2012) into fattening pigs included 7% fibre with no influences ($P>0.05$) on the production parameters (BW, ADG, FCR) or carcass characteristics (dressing out, lean meat yield, lean and fat cuts) studied.

Thacker and Haq (2008) noticed that a inclusion greater than 7.5% alfalfa meal in growing-fattening pigs was detrimental to the growth rate of pigs

during the growing period. On the other hand, the finishing period, the same percentage of alfalfa resulted in improvements in weight gain and feed intake.

Wüstholtz et al., (2017) experimented 20% alfalfa silage in the total daily DM ration in the starter phase, 40% in the grower phase and up to 50% in the finishing phase, noticing that fattening performance and carcass characteristics of the silage groups did not significantly differ from C group, but the daily gain (600 g) was at a relatively low level.

Table 3. Effect of high fiber diets on growth performances during growing-fattening phases

Specification	C	E1	E2	SEM	p-Value
Initial weight (kg)	25.00	25.67	25.00	0.796	0.9423
Final weight (kg)	76.50	81.33	81.00	1.732	0.5806
Growing period (week 0-5)					
ADFI (kg feed/pig/day)	2.221	2.372	2.262	0.032	0.1354
ADWG(kg feed/kg pig)	0.920	0.982	0.964	0.061	0.9265
FCR(kg feed/kg gain)	2.22	2.30	2.27	0.128	0.9762
Fattening period (week 5- until slaughter)					
ADFI (kg feed/kg pig)	2.745	2.933	2.708	0.052	0.1668
ADWG (kg feed/kg pig)	0.884	0.910	0.982	0.031	0.4372
FCR	3.24	3.38	2.90	0.136	0.3607

Row means with different superscripts are significantly different ($P<0.05$).

SEM = Standard Error of Mean ADFI- average daily feed intake; ADWG- average daily weight gain; FCR-feed conversion ratio

As shown within the table 4, SFA values for shoulder is significant different ($P<0.05$) on E1 group compared to C, for breast samples SFA values are significant different ($P<0.05$) on E2 group compared with E1 and C groups, and for belly samples significant differences are observed for E 1, compared to C and E2 groups.

Concerning MUFA concentrations, we noticed significant differences ($P<0.05$) for all meat samples collected. Higher values of MUFA were noticed for ham, sirloin, rack, shoulder, breast for E1 group compared with C and E2 group, while for neck and belly samples higher values of MUFA were noticed to E2 group compared with C and E1. The only significant difference ($P<0.05$) of $\Omega:3$ were recorded for shoulder samples.

Although the purpose of this experiment was not the meat enrichment in PUFA, concentration of $\Omega:6$ shown significant differences ($P<0.05$) to all meat samples collected, except neck meat samples. Higher values were noticed at breast, shoulder, rack, sirloin, ham meat samples, all within E2 group compared to C and E1, due to the fact that sunflower oil is rich in linoleic acid (51.85%).

Table 4. The fatty acid composition of the meat samples

Specification		SFA	MUFA	PUFA			
				Total	$\Omega:3$	$\Omega:6$	$\Omega:6/\Omega:3$
HAM	C	43.14	47.10 ^a	9.71 ^b	1.12	8.53 ^b	10.35 ^b
	E1	43.99	42.83 ^b	12.88 ^a	0.93	11.65 ^a	12.61 ^{a,b}
	E2	42.39	42.74 ^b	14.32 ^a	0.90	13.01 ^a	16.38 ^a
	SEM	0.374	0.912	0.881	0.054	0.853	1.189
	p-value	0.2451	0.0002	0.0088	0.2330	0.0058	0.0448
SIRLOIN	C	46.97	41.78 ^b	11.08 ^b	0.97	10.00 ^b	10.35 ^b
	E1	49.08	38.21 ^a	12.23 ^b	0.87	10.95 ^b	12.61 ^{a,b}
	E2	47.05	36.53 ^a	16.06 ^a	0.92	14.99 ^a	16.38 ^a
	SEM	0.753	1.036	0.997	0.026	1.017	1.189
	p-value	0.5412	0.0351	0.0264	0.4081	0.0293	0.0448
RACK	C	42.59	49.46 ^a	7.90 ^c	0.87	7.03 ^c	8.14 ^b
	E1	45.89	42.41 ^b	11.59 ^b	0.89	10.71 ^b	12.24 ^{a,b}
	E2	43.66	42.23 ^b	14.03 ^a	0.82	13.22 ^a	16.26 ^a
	SEM	0.938	1.575	1.151	0.035	1.162	1.595
	p-value	0.4311	0.0256	0.0080	0.8127	0.0089	0.0504
NECK	C	44.03	46.43 ^{a,b}	9.47 ^c	0.82	8.65	10.63
	E1	46.03	41.23 ^b	12.47 ^b	0.77	11.70	15.15
	E2	44.61	51.86 ^a	14.86 ^a	0.83	11.38	13.99
	SEM	0.743	2.040	0.994	0.027	0.888	1.349
	p-value	0.6406	0.0291	0.0021	0.7239	0.3806	0.4601
SHOULDER	C	43.24 ^b	46.10 ^a	8.43 ^c	0.68 ^a	7.76 ^c	11.37 ^c
	E1	45.80 ^a	42.44 ^b	11.21 ^b	0.65 ^b	10.56 ^b	16.27 ^b
	E2	44.15 ^{a,b}	40.41 ^c	13.15 ^a	0.49 ^c	12.67 ^a	26.11 ^a
	SEM	0.522	1.064	0.881	0.038	0.914	2.751
	p-value	0.0746	0.0029	0.0061	0.0004	0.0052	0.006
BREAST	C	45.47 ^a	46.10 ^a	8.31 ^c	0.68	7.63 ^c	11.33 ^c
	E1	44.75 ^a	42.44 ^b	12.46 ^b	0.58	11.88 ^b	21.25 ^{a,c}
	E2	41.60 ^b	40.41 ^c	17.56 ^a	0.48	17.08 ^a	37.51 ^a
	SEM	0.772	1.064	1.694	0.052	1.730	5.416
	p-value	0.0120	0.0029	0.0002	0.3835	0.0002	0.0932
BELLY	C	51.37 ^a	35.69 ^b	12.86 ^a	0.70 ^{a,b}	12.11 ^a	17.54
	E1	50.38 ^b	37.86 ^a	11.61 ^a	0.55 ^b	11.06 ^a	21.61
	E2	51.59 ^a	38.90 ^a	9.13 ^b	1.01 ^a	8.11 ^b	8.04
	SEM	0.247	0.634	0.729	0.095	0.790	2.974
	p-value	0.0276	0.0349	0.0300	0.0669	0.0228	0.1393

Row means with different superscripts are significantly different ($P < 0.05$); SEM = Standard Error of Mean

The PUFA $\Omega:6/\Omega:3$ ratio registered significant differences ($P<0.05$) for ham, sirloin, rack, shoulder and breast meat samples with the lowest values for group C compared to E1 and E2 groups.

The study results concerning the fatty acids composition of the meat samples collected were consistent with the findings of other authors as Tomović et al. (2016) that shown that the pigs Mangalitsa growing–finishing phase fed with sunflower meal dietary addition had lower percentage of SFA and PUFA, but higher proportion of MUFA compared with Large White pigs. Also, Lipova et al. (2017) observed in a research study on fattening pigs that the diet with sunflower addition did not decreased the PUFA/SFA ratio and n-6/n-3 ratio compared to the diet with linseed.

Table 5. Carcass traits and classification

	Experimental groups				
	M	E1	E2	SEM	p-value
Average live weight (kg)	74.43	83.06	84.02	2.196	0.1086
Average pig carcass* weight (kg)	62.15	66.55	62.15	1.498	0.4843
Yield (%)	83.51	80.10	74.17	2.471	0.3670
Average bacon thickness (mm)	9.35	11.30	13.75	0.922	0.1156
Average muscle thickness (mm)	55.80 ^a	46.95 ^{a,c}	39.45 ^c	3.200	0.0457
Average meat percentage (%)	62.45 ^a	59.60 ^a	55.35 ^b	1.365	0.0254
Class**	S (100%)	E (50%) S (50%)	U (50%) E (50%)		

* the body of a slaughtered, eviscerated pig whose blood is emitted, cut along the median line (or not cut), without tongue, hair, hooves, genitals, bones, kidneys and diaphragm.** the SEUROP - the official carcass assessment system (the classification is made according to the process of the muscular tissue from the carcass weight); class S over 60%; class E 55-60%; class U 50-55%; class R 45-50%; class O 40-45%; class P less than 40%.

Table 5 presents smaller values with significant differences ($P\leq 0.05$) were recorded concerning average muscle thickness and average meat percentage on experimental groups E1 and E2 compared to group C. Of the experimental groups, the best carcass classification results were recorded in the E1 group with 6.5% cellulose (50% Class S and 50% Class E) according to SEUROP classification system.

Authors like, Thacker and Haq (2008) noticed that a inclusion greater than 7.5% alfalfa did not affect carcass traits. Carellos et al. (2005) observed that a sunflower meal inclusion up to 16% in pig diet has no major carcass traits of finishing pigs. Trombetta et al. (2009), registered a reduction in the lean meat yield when replacing soya bean in a growing and fattening pigs diet with a mixture of field pea and potato protein.

CONCLUSION

Our research results concluded that a diet containing different fibre sources and levels, partially replacing soybean meal, does not adversely affect

productive performance on growing-fattening, but affected the average muscle thickness and the average meat percentage of the carcass. A greater dietary inclusion of sunflower flour explains the increase in n-6 PUFA observed in ham, sirloin, square, shoulder and breast samples.

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