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Effect of the Dietary By-Product *Camelina* Meal on Performances and Carcass Quality of TOPIGS Pigs

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Abstract. *Camelina* meal (CM) is a new and valuable by-product for finishing pigs. The aim of this study was to investigate the effect of replacing sunflower meal (SM) with a C18:3-n3-rich by-product, CM on the performances (body weight, BW; feed intake, FI; average daily gain, ADG, feed efficiency, FE), carcass quality (fat thickness, FT; eye muscle area, EMA; lean meat proportion in carcass (LMP, on live and slaughter animals) and classes of quality (CC) in fattening TOPIGS pigs. The fattening TOPIGS pigs (N=22; 68.45 kg ± 3.83, average weight) were assigned into 2 groups (C and E1). Group C received a compound feed with 12% sunflower meal, group E1 received the same compound feed but the sunflower meal was replaced by 12% CM, during 33 days. Fat thickness, EMA and LMP were assess on live animals using ultrasonic equipment PIGLOG 105. Animal performances such as: final average body weight (C-98.00 kg; E1-95.10 kg), FI (C-3.31 kg/day; E1-3.03 kg/day), ADG (C-0.866 kg/day; E1-0.836 kg/day) and FE (C-3.82 kg/kg; E1-3.62 kg/kg) weren't significantly affected (P>0.05) by CM. Fat thickness decreased (-23%, P<0.05), whilst EMA and LMP increased (+1%, P>0.05; + 6%, P<0.05) in the E1 group comparing to C group. Both trial groups were included in E classes according to EUROP system. In the present research work, we demonstrated that feeding finishing pigs with CM improved their quality carcass with possible benefits for human nutrition. To obtain more favorable results concerning bio-productive performances lower levels of CM inclusion are recommended.

Keywords: *Camelina* meal, by-product, performances, carcass quality, pigs

INTRODUCTION

In the last decade, pork production has facing new challenges, dictated firstly by consumer needs and demands which have focused the production towards linear and healthier meats (Alonso *et al.*, 2012) and secondly by the availability and suitability of feedstuffs.

Thus, the meat producers must adapt to this trend by supplying a broad range of products with high feeding value and at affordable prices.

Such an approach is also necessary due to the major changes in the structure of animal tissues due to modern genetics, growth and feeding (Sinclair *et al.*, 2010), which lead to the substantial decrease of n-3 polyunsaturated fatty acids (PUFA), particularly of those beneficial to the human health (>22 carbon atoms), while increasing the proportion of n-6 PUFA (Simopoulos, 2002; Wood *et al.*, 1998) which caused nutritional n-6/n-3 PUFA misbalance (>15:1 ratio in modern diets *vs.* <4:1 the optimal ratio; Simopoulos, 2002; Wood *et al.*, 1998; Yuriko *et al.*, 2010).

One of the most commune strategies used is replacing the dietary fat sources, from saturated or unsaturated fats sources with more unsaturated fats from vegetable seeds or by-products rich in healthier oils (n-3 fatty acids).

Currently, an increased attention has been focused on the industrial wastes because they are economically efficient and have a high level of nutrients. Moreover, feedstocks belonging to these categories presumably do not compete with food production and are thus very important for animal production.

Camelina meal is a new and valuable by-product for finishing pigs, resulting from the manufacture of false flax *(Camelina sativa L.)* oil reach seeds. According to our results the protein content (39.61%), particularly the amino acids (2.02% lysine; 1.80% methionine + cysteine) and also the residual oil (11.03%, crude fat) convert this meal into a very interesting alternative feeding source for pigs.

The aim of this study was to investigate the effect of replacing 12% sunflower meal with 12% by-product *camelina* meal on the performance and carcass characteristics (determined on live and slaughtered animals).

MATERIALS AND METHODS

Animals and diets. Animals were treated in accordance with the Romanian Law 305/2006 for handling and protection of animals used for experimental purposes. This study protocol was approved by the Ethical Committee of The National Research-Development Institute for Animal Nutrition and Biology-Balotesti, Romania.

The experiment used twenty-two hybrid finishing Topigs [(Landrace×Large White)×(Duroc×Pietrain)] with an average initial weight of 68.45 kg ± 3.83, for a period of 33 days. The animals were assigned to 2 experimental groups of 11 pigs each, control (C) and experimental (E1) groups. The diet of group C included 12% sunflower meal, while in the diet for group E1, the sunflower meal was replaced by 12% *Camelina* meal (rich in 18:3, n-3 PUFA). The two experimental diets (Tab. 1) were isoenergetic and isoproteic and pigs had *ad libitum* access to feed and water (nipple drinkers) during the entire experimental period. The feed intake was recorded on a daily basis.

Since CM is a by-product its nutritional value varies between the cultivars or manufacturing process, thereby it is necessary to evaluate permanently chemical composition *(Tab. 2*) and amino acids structure (*Tab. 3*) in order to establish its nutritional value. In order to avoid rancidity, the diets were manufactured on a weekly basis and stored under proper conditions of humidity and temperature.

Chemical composition of the raw ingredients and feed compound. The chemical analyses of the raw feed ingredients were performed within the laboratory of chemistry and nutrition physiology of INCDBNA, laboratory accredited according to standard SR EN ISO 17025:2005. The standard analytical methods were used according to working protocols in agreement with the similar international protocols.

We determined the content of dry matter (DM), crude protein (CP), amino acids (AA), ether extractives (EE), fatty acids (FA), crude fiber (CF), ash (Ash) per 100 g DM. The protein content were determined using the classical semiautomatic method of Kjeldahl, using the Kjeltek auto 1030-Tecator analyzer.

The ether extractives were extracted using the improved classical method by continuous extraction in solvent, followed by solvent drying and fat measurement using a Soxhlet. The fibre content was determined using the classical semiautomatic method Fibertec-Tecator, and the ash was measured by burning at 550^{o}C until constant mass was obtained (Criste *et al*, 2003). The nitrogen-free extractives were calculated using the following formula: NFE=DM-(CP+EE+CF+Ash). The metabolisable energy was calculated using a regression equation developed by the "Oskar Kellner" Institute: ME = 5.01 x DP + 8.93EE+ 3.44CF + 4.08DNFE (Stoica and Stoica, 2001).

The aminoacids were determined by reversed phase high performance liquid chromatography (RP-HPLC), deriving in pre-column and UV detection. The amino acids chain from the protein molecule was broken by acid hydrolysis with HCl 6N. The sample was derived with OPA reagent (ortho-phthalaldehyde), AMP (mercaptopropionic acid and FMOC (9-fluorenil-methyl-chloroformate). The sample was processed with a HPLC Surveyor Plus, with reading at 338 nm. The concentration is calculated by relating the peak area to the calibration curve.

The sulphur aminoacids cystine and methionine, were oxidized with performic acid to cysteic acid and methionine sulphone before hydrolysis. Cystine is determined as cysteic acid, but is calculated as cystine using its molar mass. Methionine is determined as methionine sulphone, but is calculated as methionine using the molar mass of methionine.

The detailed chemical composition of fatty acids was determined by gas chromatography using a Perkin Elmer-Clarus 500 (data not shown).

Animal performance. In the beginning and at the end of the experiment, the animals were weighed individually, to determine the following parameters: body weight, average daily gain, daily consumption of feed compound, feed efficiency and feed conversion (FC).

Carcass characteristics. After 33 days we determined carcass quality for all live animals using ultrasonic equipment PIGLOG 105, SFK-Technology, Denmark. Thus, for the evaluation of meat production on the live animal, the dorsal fat layer was measured at two distinct points, between lumbar vertebrae 3 and 4, at 7 cm from the median line, and between ribs 3 and 4, at 7 cm from the median line. The muscle eye area was measured between ribs 3 and 4, at 7 cm from the median line. Using the body weight, the information was processed by the software of the instrument in order to estimate the proportion of muscle tissue in the carcass.

Twelve hours before slaughter the access of animals to feed was restricted. All pigs (n=22), with an average weight of 96.55±4.26 kg, were transferred (30 minutes travel) to an authorized slaughter facility, where they were stunned, bled and cut; the carcasses were graded with a FOM-2424, Denmark device fitted with optical probe and microprocessor. This method implies measuring the lean meat proportion of the carcass using the fat layer thickness and the muscle thickness measured at ribs 3 and 4 (Movileanu, 2008).

Fatty acids analyses. After the carcasses were refrigerated (30 minutes at +4^{o}C), samples were collected from two muscles (*Longissimus dorsi* and *Semitensinossus*) and from organs, and analyzed for the fatty acids profile, endogenous and exogenous antioxidant enzymes and for the concentration of malondialdehyde (data not shown).

Statistical analyses. The effects of CM on pigs performances and carcass quality were analyzed by one-way ANOVA StatView version 5.0. The results were expressed at mean values and standard deviation. The differences among treatments were considered significant at $P<0.05$.

RESULTS AND DISCUSSIONS

The nutrient profile including the amino acids of CM used in the finishing pig diets (Tab.1) is shown in *Tables 2* and *3*.

Camelina meal consist of about 3491 kcal/kg metabolisable energy (ME), 39.61% crude protein, 11.03% ether extractives and about 9.59 crude fiber, on dry matter bases. The ME and CP of the C and E1 were 3057 Kcal/Kg and 15%. The biological value of CP is given by the content of amino acids. According to our results CM consist of at least 16 AA, of which 8 are essential (*Tab. 3*). Leucine, valine and lysine (2.59%; 2.12% and 2.02%) were the predominant among the EAA in the CM.

Tab. 1

Experimental diets composition and calculated nutrient analyses of finishing TOPIGS pigs

Items	Dietary treatment 0-4	
Ingredients	Control	E1
Corn	52.84	42.08
Barley	10.00	16.00
Rice flour	12.00	17.00
Soybean meal (44%)	8.00	9.00
Sunflower meal (31.94%)	12.00	-
Camelina meal	-	12.00
Sunflower oil	1.00	0.20
DL-methionine	0.02	-
L-Lysine	0.32	0.18
Calcium carbonate	1.57	1.62
Monocalcium phosphate	0.75	0.42
Salt	0.40	0.40
Choline premix	0.10	0.10
Vitamin-mineral premix P3+4	1.00	1.00
Calculated analysis		
ME Kcal /Kg	3058.00	3057.00
CP (%)	14.63	14.94
Lys. B (%)	0.87	0.88
Met.+cys. B (%)	0.59	0.60
Fiber (%)	5.16	4.21
Calcium (%)	0.80	0.80
Total P (%)	0.65	0.65

Note: C-12% sunflower meal; E1-12% camelina meal.

Tab. 2

Weende analysis of the sunflower meal and of the *Camelina* meal

Items (g/100g DM)	Chemical composition of the main raw ingredients used in the experimental diets	
	Sunflower meal	Camelina meal
DM (%)	89.77	91.31
ME (Kcal/kg)	2553	3491
CP (%)	31.94	39.61
EE (%)	1.79	11.03
CF (%)	19.03	9.59
Ash (%)	7.31	4.97
Carbohydrates (%)	48.73	35.70
Ca (%)	-	0.40
P (%)	-	0.73

Other EAA ranged between 0.94% to 1.98% in the following order: isoleucine, arginine, phenylalanine, threonine and methionine. From NEAA, important quantities of glutamic acid, aspartic acid and glycine (6.43%, 3.37% and 2.01) were noticed. Other, NEAA ranged between 0.84% to 1.85% as follow: alanine, serine, cystine, tyrosine. Some of this amino acids (lysine, methionine, cystine and tryptophan) are critical in pig nutrition (NRC, 1998).

The content of EAA lysine and methionine in CM was higher (+1.88% and respectively +1.38%) then sunflower meal (by Degussa, 1997). Lysine and methionine are usually the first limiting amino acids in pig nutrition (NRC, 1998). Thus, this by-product could be a promising sources of valuable protein for finishing pigs nutrition.

Apart from protein, fat and fiber of this meal also contain important quantities of vitamins E known for its antioxidant properties and 5% minerals (Matthäus and Zubr, 2000). Among minerals in CM according to our analyses we found phosphorus (0.40%) and calcium (0.70%). This raw ingredient may also contain other minor constituents, with no nutritive value, such as: glucosinolates, trypsin inhibitors or erucic acid, etc. (Budin *et. al.,* 1995; Schuster and Friedt, 1998) but which, in specific concentrations, hinder the efficient use of the nutrients and affect animal health (Tripathi and Mishra, 2007). Future agronomic advancements *via* genetic modification (Budin *et al.,* 1995) will eliminate the amount of anti-nutritional factors from the seeds, thus improving the quality of the meal and its utilization in animal diets.

Tab. 3

Amino acids analyses of the *Camelina* meal

Amino acids (% CP)	Camelina meal
Essential amino acids*	
Arginine	1.864
Lysine	2.021
Phenylalanine	1.656
Leucine	2.594
Isoleucine	1.978
Valine	2.123
Methionine	0.941
Threonine	1.539
Total EAA	14.716
Non-Essential amino acids**	
Aspartic acid	3.365
Glutamic acid	6.432
Serine	1.557
Glycine	2.010
Alanine	1.850
Cystine	0.862
Tyrosine	0.843
Total NEAA	16.919
Total AA	31.635

Note: Essential amino acids*-EAA; Non-Essential amino acids**-NEAA

Generally, the amounts of nutritional components or of those with no nutritional value, trapped in CM after oil extraction, may vary according to seeds varieties, the growth conditions for the crop, and particularly to the level of phosphorus in the soil (Matthäus and Zubr, 2000) or according to the technological process of seeds processing, by solvent (hexane) or cold press extraction (Hebean *et al.,* 2010).

Due to the protein content and especially the residual oil this by-product is already being evaluated as a source of omega-3 in feeds for fish, beef, egg-laying hens (Rokka *et al.,* 2002), poultry, and dairy production (Pilgeram *et al.,* 2007). However, limited information are available about inclusion of this vegetable ingredient in finishing fattening pigs diets.

Animal performance. *Table 4* shows the performance of the finishing pigs. Initial average body weight of the experimental animals was 68.48±3.53. After 33 experimental days, the animals were weighed individually and the results were processed statistically and used to calculate other parameters such as the average daily gain, feed efficiency (kg feed: kg gain) and feed conversion (kg gain: kg feed).

The BW of pigs fed CM diet was 3% lower than that of the control group, ($P>0.05$). There weren't significant differences ($P>0.01$) in ADG between the controls and CM fed pigs

during experimental period. However, the use of CM slightly decreased feed intake of pigs (-8%) during the finishing period. There were a slightly reduction by 4% in the feed efficiency and by 5% in the feed conversion of pigs fed CM diet comparing to SM diet.

Tab. 4

Effects of using *Camelina* meal on productive performance of finishing TOPIGS pigs

Items	C	E1
No. of pigs, animals/group	11	11
Age: Finishing period, days	33	33
Body weight: Initial, kg	69.40±2.11	67.50±4.95
Final, kg	98.00±2.79	95.10±5.74
Average daily gain at: 33 day, g/day	0.866±0.07	0.836±0.07
Feed intake, kg/day	3.31	3.03
Feed efficiency, kg feed/kg gain	3.82	3.62
Feed conversion, kg gain/kg feed	0.25	0.24

Note: Different letters between dietary treatments denote significant differences (ANOVA; $p<0.05$).

Previous reports have demonstrated that the addition of CM in monogastrics or rabbit diets has led to scarce results. The literature has a lot of reports on poultry and rabbits, while the reports on pigs are virtually zero. Aziza *et al.* (2010) using 10% CM into broiler diet during 42 days, did not observed affected significantly the ADG or feed efficiency. Peiretti *et al.* (2007) during a trial of 50 days on various levels (10% or 15%) of false flax (*Camelina sativa* L.) seed in the fattening rabbits diet, didn't obtain any significant differences among the groups regarding live weight, ADG, feed intake or feed efficiency. Kakani *et al.* (2012) examined the effects of feeding extruded defatted *Camelina* meal (5% or 10%) to commercial laying hens and concluded that there was no reduction in the daily egg production, in feed intake or there was a reduction in hen body weight in the *Camelina* meal fed groups. Cherian *et al.* (2009) in a 80 day trial on ISA Brown Leghorn laying hens using in their diets 5% or 10% *Camelina* meal, found no difference in hen-day egg production or feed intake compared to the control. However, when the inclusion level of CM was 15%, feed intake (98.7 g/hen) and hen-day egg production were lower ($P<0.05$) comparing to control. Contrary, Ryhanen *et al.* (2007) observed that inclusion of 5 or 10% *Camelina* expeller cake obtained by cold pressing in broiler diet (37 days) significantly reduced growth performances, feed intake and feed efficiency.

In our study, although the results on the production performance in group E1 compared to C were slightly lower ($P>0.05$), the health status of animals (blood parameters) was not affected (data not published).

Carcass quality. In the recent years, both in Romania, and in the developed countries, the trend is to produce animals with a thin layer of fat, concomitantly with the increase of n-3 PUFA levels of the meat using modern hybrids and various feeding strategies (Alonso *et al.,* 2012; Wood *et al.*, 1998). One of the most used sources of n-3 fatty acids in monogastric animals feeding was the flax (seeds and oil), (Romans *et al.,* 1995). Recently, the *Camelina* oil and meal were tested as means to increase the amount of dietary lipids (Hăbeanu *et al.,* 2009; Pilgeram *et al.,* 2007; Rokka *et al.,* 2002). However, the data on the effect of *Camelina* meal on pig carcass quality are limited.

The indices of pig carcass quality after determination on live animals or after slaughter are shown in *Table 5*.

Determinations carcass quality on live pigs. In our study, CM with 11.03% residual oil decreased the FT (1.29 times lower compared to C, $P<0.05$), whilst EMA and LMP recorded important increases (1 time higher, $P>0.05$ and 1.05 times higher, $P<0.05$, respectively, compared to C).

Tab. 5

Effects of using *Camelina* meal in diets of finishing TOPIGS pigs
on qualitative parameters of carcass

Carcass quality	C	E1
Determination on live pigs*:		
- fat thickness**, mm	$13.13^{a} \pm 1.76$	$10.15^{b} \pm 2.03$
- eye muscle area***, mm^2	47.36 ± 2.73	47.75 ± 6.14
- lean meat proportion in carcass, %	$57.43^{a} \pm 1.85$	$60.47^{b} \pm 2.10$
Determination on carcass (after slaughter)****:		
- lean meat proportion in carcass, %	$57.56^{a} \pm 2.87$	$60.18^{b} \pm 1.96$
Classes of quality	E	E

Note: Different letters between dietary treatments denote significant differences (ANOVA; $p<0.05$);
*Measuring done with PIGLOG 105; **Fat thickness measured between ribs 3 and 4, at 7 cm from the median line; ***Eye muscle area measured between ribs 3 and 4, at 7 cm from the median line; ****Measuring done with FOM-2424.

Contrary to our results, when 15% flaxseed was used in the diets of pigs (Romans *et al.* 1995) for 7, 14, 21, or 28 d prior to slaughter the production traits or back fat thickness and lean meat percentage were not affected. However, there are evidence that the type of fat fed to pigs play an important role in fat metabolism and thus influence animals leaner (Pettigrew and Esnaola, 2001). Thus, Heckart *et al.* (1999) suggest that increasing the level of PUFA containing more than 18 carbon atoms via dietary addition make animals leaner, most likely due to the reduction of lipogenesis rate.

According to Mourot *et al.* (1995), the increase of linoleic acid (18:2n-6, 2.5%) level, using rapeseeds oil in pig diets, increased body fat and the synthesis potential of the long-chain lipids of the fat. This aspect is particularly important because presently, because of processing, the human diets are increasingly poor in essential nutrients such as fatty acids n-3 PUFA with more than 22 carbon atoms (Hong-yan *et al.*, 2011; Simopoulos, 2002; Wood *et al.*, 1998). So, there is interest in increasing the concentration of these fatty acids in pork.

Determinations of carcass quality on slaughtered pigs. After slaughtering the values obtained by FOM-2424 measurements, for the lean meat proportion in carcass were quite similar to those obtained by PIGLOG 105, which allowed us to determine directly at the growers carcass parameters. Using these two methods we graded the carcasses according to EUROP system. The proportion of muscular tissue in carcass weight exceeded 55%, thus all carcass were included in E classes of quality (*Tab. 5*).

CONCLUSION

In the present research work, we demonstrated that CM due to the content in essential amino acids such as lysine and methionine is a promising sources of valuable protein for finishing pigs nutrition.

Feeding finishing pigs with 12% CM didn't reduce significantly the bio-productive performances, while carcass indices, EMA and LMP, were improved.

In perspective, due to the residual oil rich in n-3 fatty acids this by-product can be used in the compound feed for the finishing pigs to modify the fatty acid profile with possible benefits for human nutrition.

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