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EFFECTS OF THE EXTRUDED LINSEED AND WALNUT MEAL ON SOME QUALITY CHARACTERISTICS OF *LONGISSIMUS DORSI* AND *SEMITENDINOSUS* MUSCLE OF PIGS

Lavinia IDRICEANU[1], Silvia MIRONEASA[2], Anca GHEORGHE[1], Nicoleta Aurelia LEFTER[1], Madalina IUGA[2], Daniela Mihaela GRIGORE[3], Mihaela HABEANU[1]

[1]National Research-Development Institute for Biology and Animal Nutrition, Calea Bucuresti No. 1, Balotesti, Romania
[2]"Stefan cel Mare" University of Suceava, Str Universitatii, No. 13, Suceava, Romania
[3]Research and Development Institute for Bovine Balotesti, Şos. Bucuresti-Ploiesti, Balotesti, Romania

Corresponding author email: anca.gheorghe@ibna.ro

Abstract

The trial was conducted to evaluate effects of the addition of extruded linseed and walnut meal (ELW) on meat quality parameters. For a 30-days period, 40 TOPIGS pigs (body weight 13.58±0.37 kg) were allotted in two dietary treatments: control, M and experimental E (with 8% mix of ELW). At slaughter (32 ± 4.5 kg final body weight), meat samples from Longissimus dorsi (LD) and Semitendinosus (ST) were collected (n = 3 pigs/group), and analysed for pH, colour and texture profile. The pH of LD muscle was lower (-2.33%, P<0.001) in E diet. LD muscle from pigs fed E diet, registered a lower (-4.20%, P<0.001) value of Lightens (L) and a higher value of redness (a) by 3.07 (P<0.001) compared to M. The ST muscle have registered lower (P<0.001) values of L (-7.30%) and a* (-22.84%) in E diet compared to M diet. Addition of extruded linseed and walnut meal in pigs diet have no negative influence on meat quality parameters.*

Key words: *linseed, meat quality, pork, walnut.*

INTRODUCTION

In past years, consumer interest in the relationship between diet and health has increased the demand for a high quality of the foods. Since 2010, in our country it has been observed that consumer preference towards meat quality have started to increase, even if this means paying a higher price (Food Report Romania, 2016). According to FAO (2012), pig meat is the most consumed meat in the world, due to the nutritional characteristics (proteins with high biological value and optimal amino acid composition) and completely usable in human metabolism (Karlovic et al., 2009).
In Romania, pork accounts for more than half of the total annual meat consumption per capita. In the last recorded, the National Institute of Statistics (2018) reported that in Romania, the average annual pork consumption increased to 38.3 kg per capita, compared to pork consumption in 2017 (36.1 kg/capita). In a recent study, Pogurschi et al. (2018) noticed that there are no significant differences in meat consumption between urban and rural areas in Romania.
It is known that animal nutrition can have a major impact on meat quality. Thus, with the help of diet, we can beneficially modulate the quality of the animal product, so that it has a positive impact on the health of consumers (Habeanu et al., 2019).
The meat quality is complex and multivariate, which is influenced by factors as the breed, genotype, feeding, pre-slaughter handling, stunning, and slaughter method, chilling and storage conditions (Rosenvold and Andersen, 2003; Andres et al., 2007). The physical measurements used to determine meat quality are pH, colour, and texture (hardness, springiness, gumminess etc.).
Given the importance of the pork quality, to meet consumer requirements, the producers are looking for different ingredients with low costs and high nutritional value, to introduce them into the pig's diet, to obtain high quality meat without affecting the animal's health (Habeanu et al., 2018).

In present, alternative nutritional sources are constantly being search, since feed price make up more than 65% from production costs, which will likely persist due to increasing global demand for the grains rather than to the pig sector.

Linseed (*Linum usitatissimum*) is one of the oldest cultivated plants, and primarily it was used for fibre (linen) and oil production. Starting with the 90s, it was discovered that linseeds oil is rich in polyunsaturated fatty acids (35%), notably alpha-linolenic acid and conjugated linoleic acid. Thus, the linseeds are used in animal nutrition to alter the fatty acid profile of meat (Habeanu et al., 2017; Heuzé et al., 2018; Habeanu et al., 2019).

Linseed meal is also rich in protein (30-39% protein, but with a low content in lysine), and can be used in pigs diet as long as the diets are correctly balanced (Leterme et al., 2015). An inconvenience is the fiber content and antinutrients such as linamarin. According to McDonald et al. (2002), if linseed is not processed correctly, this can be toxic to animals (especially monogastric). According to Delgado-Licon et al. (2009), there is a strong correlation between the extrusion procedure and the content of bioactive compounds and antioxidant capacity in the end product. Thus, it has been shown that the extrusion process can lead to a reduction in the contents of bioactive compounds, including antioxidant activity (Giannico et al., 2009; Czech et al., 2017).

Walnut (*Juglans regia*) is a rich source of polyphenols, omega fatty acids, dietary fiber and it is known that are a potential source of antioxidants with a beneficial effect on pigs health (Ghasemi et al., 2011; Gheorghe et al., 2018, Habeanu et al., 2019). An inconvenience is that the walnut by-products have high-fat content and become rancid in a very short time (Brunschwig, 2003). According to Heuzé et al. (2017), in the 19^{th} century, the walnut meal was used commonly in pigs diet.

Therefore, the purpose of this study was to evaluate the effect of the addition of 8% (5:3 wt/wt) extruded linseed and walnut meal (ELW) on some quality characteristics of pigs muscle.

MATERIALS AND METHODS

The animals were treated in accordance with the Romanian Law 305/2006 for handling and protection of animals used for experimental purposes.

The trial was conducted on the experimental farm of INCDBNA Balotesti, according to Law 43/2014/Romania, and all the experimental procedures were approved by the Ethical Committee.

Animals, diets, and sampling

The trial was conducted on 40 growing pigs, of commercial hybrid TOPIGS, maternal line format, from the crossing of two breeds Large White × Hybrid (Large White × Pietrain) and the paternal, of Talent, terminal boar mostly Duroc, initial body weight (BW) 13.58 ± 0.37 kg and age of 81 ± 3 days.

During a period of 30 days, the animals were allotted randomly into two dietary treatments (20 pigs/group, 2 replicate/group): control group (M) was fed with a conventional diet based on corn, triticale and soybean meal, and experimental group (E) with an addition of 8% (5:3 kg/kg) mix of ELW into the basal diet (Table 1). The feed was given in the pelletized form. The water and feed were given *ad libitum* throughout the entire experiment.

At the end of the experimental period, the pigs (n = 3/treatment) were slaughtered at final BW of 32 ± 4.5 kg, for sample collection. The samples (about 200 g) were collected from the *Longissimus dorsi* (LD) and *Semitendinosus* (ST) muscles. All the samples were individually vacuum-packed, labeled and frozen at −18°C until analyzed.

Physical properties determination

All the muscle samples were analysed for pH, colour, and texture, at the Food Engineering Faculty, "Ştefan cel Mare" University, from Suceava, Romania.

Before analyse, the muscle samples were removed from the freezer and thawed overnight (approximately 15 h) at 4 ± 1°C.

Table 1. Ingredient and nutrient composition of pigs diet

Ingredients, %	M diet	ELW diet
Corn	35.83	32.33
Triticale	25.00	25.00
Rice meal	15.00	15.00
Soybean meal	10.00	5.00
Extruded linseed: walnut meal (5:3 wt:wt)	0	8.00
Sunflower meal	5.00	5.00
Corn gluten	2.00	3.00
Milk replacer	3.00	3.00
Vegetable oil	0.70	0
DL-Methionine	0.00	0.06
L-Lysine	0.34	0.52
Calcium carbonate	1.78	1.76
Monocalcium phophate	0.04	0.02
Phytase	0.01	0.01
Salt	0.20	0.20
Choline premix	0.10	0.10
Vitamin-mineral premix[1]	1.00	1.00
Analysed composition, %		
Dry matter	88.43	88.18
Crude protein	17.10	17.30
Lysine	1.05	1.05
Methionine+Cystine	0.67	0.67
Calcium	0.90	0.90
Phosphorus	0.70	0.70
Crude fiber	4.66	4.97
Crude fat	4.37	4.80
Metabolisable energy, ME (MJ/kg)[2]	12.67	12.66

[1]Contained per kg diet: 10000 IU vitamin A; 2000 IU vitamin D3; 30 IU vitamin E; 3 mg vitamin K3; 2 mg vitamin B1; 6 mg vitamin B2; 20 mg vitamin B3; 13.5 mg vitamin B5; 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 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.

[2]ME calculated based of feed composition using regression equations (NRC, 1998).

The sample pH was performed in triplicate according to SR ISO 2917: 2007. The pH was determined using a portable pH Meter (HACK, Germany). Before the pH determination, the pH-meter was calibrated using buffer solutions of pH 7 and pH 4. Muscle samples (5 g) were minced and mixed with 5 ml distilled water (tissue-water mixture), then the electrode was inserted in the tissue-water mixture for pH measurement.

The colour was instrumentally measured using a Chroma Meter CR-400 (Minolta Co. Ltd, Tokyo, Japan) calibrated with a white ceramic tile on D65 illuminate. The colour values were expressed in CIE L*a*b* colour system (CIE, 1976) Lightness (L*), redness (a*) and yellowness (b*). The colour was measured concerning lightness (L*: 0 = black, 100 = white), and 2 colour coordinates a* equal to red (positive) or green (negative) and of b* equal to yellow (positive) or blue (negative). Colour was determined on the fat-free surface area of the muscle. The muscle colour measurement was performed in triplicate for each sample, using different instrument orientations.

Textural properties analysis was performed using a Perten TVT 6700 texturometer. Before analyse the all the meat samples were cut so that they were shaped like a cylinder with a diameter of 15 mm and a height of 25 mm. The meat samples were subjected to a double cycle compression, which was determined with a cylinder probe 20 mm diameter, stainless steel. The method allows the determination of firmness, springiness, resilience, cohesiveness, gumminess, and chewiness.

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). Differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSIONS

Currently, consumers are more knowledgeable regarding the nutritive value of the food and have become more interested in food quality. Regarding the meat quality, generally, the consumers are more interested in colour, and texture.

The present study was performed to obtain information about the effect of the addition of 8% (5:3 kg/kg) extruded linseed and walnut meal mix, on some quality parameters (pH, colour, and texture) of the muscles with the major economic importance (*Longissimus dorsi* and *Semitendinosus)* in pigs. In our previous studies we show the importance of these feeding ingredients on fatty acids profile and animal health (Gheorghe et al., 2018; Habeanu et al., 2019).

The pH, colour and texture parameters are some of the most important quality attributes of meat (Lee et al., 2012). These parameters depend on species and muscle type, feeding, slaughter method etc. (Migdał et al., 2007). The pH is the most direct way to acquire information on meat quality characteristics (Lefter et al., 2013; Tomivic et al., 2014).

In the current study, there was registered a pH decrease in the LD muscle (>2.3%; P = 0.001) as effect of dietary inclusion of extruded linseed and walnut mix (Table 2).

According to Tomivic et al. (2014), the ultimate meat pH is reached at 5.3-5.8 at various periods post-mortem. The pH results obtained in our study are in range and are consistent with the results obtained by other authors (Wiecek et al., 2008; Lee et al., 2012; Lefter et al., 2013; Tomovic et al., 2014; Furtado et al., 2019). Contrary to our results, regarding meat quality traits, Corino et al. (2002) and Riley et al. (2000), did not show any dietary effect on pH values.

Table 2. pH and instrumental colour parameter in pigs muscle

Muscle	Parameter	M[1]	E[2]	SEM[3]	*P-value*
Longissimus dorsi	pH	5.57[a]	5.44[b]	0.03	*0.001*
	L*	52.60[a]	50.38[b]	0.52	*0.004*
	a*	1.21[b]	3.72[a]	0.57	*0.000*
	b*	9.75	8.99	0.24	*0.110*
	Chroma C*	9.82	9.73	0.18	*0.829*
Semitendinosus	pH	5.59	5.58	0.01	*0.101*
	L*	49.31[a]	45.71[b]	0.82	*0.001*
	a*	3.24[a]	2.50[b]	0.18	*0.016*
	b*	9.74	9.70	0.23	*0.942*
	Chroma C*	10.27	10.02	0.22	*0.637*

[1]M: control group;
[2]E: experimental group;
[3]SEM: standard error of the mean;
L*(Lightness), a* (Redness), b* (Yellowness);
[a, b]Row means with different superscripts differ significantly (P<0.05).

The LD and ST muscle, colour from pigs fed ELW diet had similar Chroma values with the control group and (in ST muscle was noticed a little higher value compared with LD muscle). The LD muscle of pigs fed ELW diet resulted in significantly lower L* (<4.20%; P=0.001) and a higher a* (3.07-fold; P = 0.001) values, indicating a shift to darker and redder meat compared to control diet. Similar results of LD colour were obtained by Okrouhlá et al. (2013). The ST muscle, of pigs fed ELW meal, resulted in a lower L* (<7.30%; P<0.001) and a* (<22.84%; P = 0.016) values, suggesting a shift into darker and less red meat, compared to control group. A darker appearance (L*) of the meat was also obtained by Riley et al. (2000) and Okrouhlá et al. (2013), who fed pigs with linseed. Contrary to our results, previous studies have not reported any effect on meat colour when linseed was included in pig diets (Bee et al., 2008; Corino et al., 2008; Juáreza, 2011).

The most important parameters that they have in view when they buy meat are tenderness, juiciness, gumminess etc. (Migdał et al., 2007; Warner et al., 2010). There are studies (Bindon & Jones, 2001; Maltin et al., 2003) which pointed that most consumers complained about the meat hardness.

From our knowledge, data regarding the effect of the addition of extruded linseed and walnut meal in pigs diet in the growing phase, on the textural parameters, are limited. In the present study, as presented in Table 3 no significant differences were recorded between groups. However, we observed that the pigs fed ELW diet, produced meat with lower hardness for LD (-7.73%; P>0.05) and ST (-23.18%; P>0.05) compared to the control group.

Table 3. Textural parameters in pigs muscle

Muscle	Parameter	M[1]	E[2]	SEM[3]	*P-value**
Longissimus dorsi	Hardness (g)	1431.0	1320.5	290.2	*0.890*
	Springiness (adm)	1.0	1.0	0.001	*0.728*
	Resilience (adm)	3.0	3.0	0.32	*0.970*
	Cohesiveness (adm)	0.4	0.4	0.03	*0.486*
	Gumminess (g)	563.3	614.1	154.7	*0.905*
	Chewiness (g)	563.9	614.1	154.7	*0.906*
Semitendinosus	Hardness (g)	1754.0	1347.5	238.5	*0.508*
	Springiness (adm)	1.0	1.0	0.001	*0.963*
	Resilience (adm)	3.6	2.8	0.46	*0.546*
	Cohesiveness (adm)	0.4	0.4	0.04	*0.768*
	Gumminess (g)	728.9	541.4	147.9	*0.634*
	Chewiness (g)	729.4	541.9	147.9	*0.634*

[1]M: control group;
[2]E: experimental group;
[3]SEM: standard error of the mean;
*Means within rows do not differ significantly (P>0.05).

Lower values were also obtained for gumminess (<25.73%; P>0.05), and chewiness (<25.71%; P>0.05) in the ST muscle of pigs fed ELW diet compared to control group. Regarding the LD muscle, this recorded higher values for gumminess (>9.01%; P>0.05) and chewiness (>8.90%; P>0.05) compared to the control group.

Similar textural parameters of meat were also obtained by Wiecek et al. (2008) from pigs fed with linseed oil and slaughtered at 23 kg BW. However, previous studies feeding pigs with linseed also reported insignificant differences in physical meat quality parameters (Corino et al., 2008; Nurnberg et al., 2011).

CONCLUSIONS

The addition of 8% (5:3 kg/kg) extruded linseed and walnut meal mixture in growing pigs diet did not influence negatively the physical characteristics of the qualitative parameters of *Longissimus dorsi* and *Semitendinosus* muscle. Also, following the results mentioned above, we can recommend the inclusion of the mixture of extruded linseed and walnut in the pigs diet.

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