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Omega 3, 6, 9 Enhanced Goat Meat (*Omega*-Chevon) from Flaxseed and Canola Fed Meat Goats

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Abstract

With growing obesity and cardiovascular disease concerns, the meat industry aims to reduce fat content in meat products. Currently Omega Fatty Acid (FA) enhanced beef and eggs are being marketed in the US, but Omega enhanced goat meat (Omega-Chevon) has not been developed. Meat goats were fed ground flaxseed and canola supplemented feed for 90 days. There were no palatability, weight, or health issues in meat goats fed canola and flaxseed supplemented feed. Chevon from goats fed canola and flaxseed had significant (P<0.05) increase in Omega 3, 6 and 9 FA, compared to the control diet. However, Chevon from goats fed flaxseed diets had a marked increase (P<0.05) in Omega 3, 6, and 9 FA compared to those fed control and canola supplemented diets. Chevon from Spanish and Myotonic goats fed flaxseed had increased (P<0.05) Omega, 3, 6 FA compared to control. However, C18:1 (Omega 9) FA was higher in Chevon from Myotonic goats vs. Spanish goats, whereas Chevon from both Spanish and Myotonic goats were higher (P<0.05) in C20:1 (Omega 9) FA compared to Chevon from those fed the control diet. These data demonstrate that Omega Chevon can be produced by supplementation of the meat goat diet with canola and flaxseed.

Keywords

meat goat omega, Chevon, flaxseed, canola

1. Introduction

Goat production continues to gain attention because of the potentially beneficial impact of Chevon (goat meat) consumption on human health (James & Berry, 1997). Chevon is the most consumed red meat worldwide. However, in the United States, goats have traditionally been used for milk and fiber production, therefore Chevon production and consumption has remained limited compared to beef

(Glimp, 1995). Chevon is a high animal protein source that has less fat and very little cholesterol than beef or lamb. Since goats deposit fat mostly internally as opposed to intramuscularly, Chevon is a leaner red meat compared to beef, lamb or pork (Banskalieva, Sahlu, & Goetsch, 2000; Bas, Dahbi, El Aich, Morand-Fehr, & Araba, 2005; Ding, Kou, Cao, & Wei, 2010; Limέa, Alexandre, & Berthelot, 2012; McDonald & Scott, 1977; Pratiwi, Murray, & Taylor, 2007). Skinless chicken is 40% higher in saturated fat, whereas beef is 50%-60% higher than cooked goat meat (James & Berry, 1997). Goat meat also contains a relatively high amount of linoleic, linolenic, and arachidonic acids, which are Polyunsaturated Fatty Acids (PUFA). It has been shown that diet can affect the type of lipids found in goat tissues (Banskalieva et al., 2000; Ding et al., 2010; Tan et al., 2011), therefore Chevon is a good starting meat for enhancement with omega-3 fatty acids for human consumption.

Flax (*Linum usitatissimum*) an oilseed, has been demonstrated to have multiple human health benefits, particularly in cardiovasucular disease (CVD), obesity and immunity (Adlercreutz, 2007; Bhathena et al., 2003; Nelson, Stevens, & Hickey, 2007). Flax contains about 20% alpha linolenic acid, an essential *omega-3* fatty acid, a precursor for Eicosapentaenoic Acid (EPA), which is a precursor for eicosanoids, hormone-like compounds involved in the immune response (Cathcart, Lysaght, & Pidgeon, 2011; Hogenkamp et al., 2011; Kapoor & Huang, 2006). The precursor EPA can elongate further to Docosahexanoic Acid (DHA), an *omega-3* fatty acid that is essential for cell membrane integrity, as well as brain and eye health (Jicha & Markesbery, 2010; Kiecolt-Glaser, Belury, Andridge, Malarkey, & Glaser, 2011; Lauretani et al., 2007; Pallebage-Gamarallage, Lam, Takechi, Galloway, & Mamo, 2012). Much attention has been given to flax consumption as being beneficial for the management of blood pressure, CVD, diabetes, and immune function (Adlercreutz, 2007; Barre, Mizier-Barre, Griscti, & Hafez, 2008; Basch et al., 2007; Bhardwaj, Hamama, Narina, & Parry, 2012; Bhathena et al., 2003; Farran et al., 2008; Fritsche & Cassity, 1992; Hillyer, Sandiford, Gray, & Woodward, 2006; Lessard, Gagnon, & Petit, 2003; Leyva et al., 2011; Mandaşescu et al., 2005; Park, H. J., Park, J. S., Hayek, Reinhart, & Chew, 2011; Saini, Harjai, Mohan, Punia, & Chhibber, 2010; Thies et al., 2001; Wallace, Miles, & Calder, 2003). Past research indicates that products, such as eggs (Antruejo et al., 2011; Raes et al., 2002; Schumann, Squires, Leeson, & Hunter, 2003; Yalçin & Unal, 2010) and beef (Juárez et al., 2011; Kronberg, Scholljegerdes, Lepper, & Berg, 2011; Nassu et al., 2011; Quinn et al., 2008; Scholljegerdes & Kronberg, 2010), from animals fed flax have increased levels of *omega-3* fatty acids. To date *omega*-fatty acid enhanced eggs are currently on the market. This has led to a renewed interest in flax production and feeding flax to livestock. Currently flaxseed feed is being sold in the Midwest as one to improve immune function and quality of hair. However, thus far our study is one of the first to examine flaxseed as a supplement for omega-enhanced goat meat production.

Canola (*Brassica napus*) oil contains 55% of the monounsaturated fatty acid (MUFA); oleic acid, 25% linoleic acid and 10% alpha-linolenic PUFA and only 4% of the Short Chain Fatty Acids (SFA) that have been implicated as factors in hypercholesterolemia. It is derived from a cultivar of rapeseed that was selectively bred from old varieties in Canada to have marginal erucic acid, a fatty acid with pathogenic potential in diets high in the original rapeseed oil in experimental animals (Dupont et al., 1989). Since then, low erucic acid canola oil has been developed and (Dupont et al., 1989; Rzehak et al., 2011; Wang et al., 2010), is now the most widely consumed food oil in Canada, Generally Recognized As Safe (GRAS) by the US Food and Drug Administration, and the Department of Health and Human Services. The fatty acid composition of canola oil is made up of less than 10% SFA, 8%-10% PUFA in a ratio of linoleic to linolenic acids between 4:1 and 10:1, the remainder being MUFA. Studies have shown that canola has human (Bourre, 2005, 2007; Damude & Kinney, 2007; de Lorgeril & Salen, 2004; Flickinger, 2007; Garman, Mulroney, Manigrasso, Flynn, & Maric, 2009; Gebauer, Psota, Harris, & Kris-Etherton, 2006; Ghafoorunissa, 1998; Gillingham, Gustafson, Han, Jassal, & Jones, 2011; Ristić-Medić, Ristić, & Tepsić, 2003) and animal health benefits and have been manipulated in animal diets to produce fat healthy animal products for human consumption (Bourre, 2005; Chichlowski, Schroeder, Park, Keller, & Schimek, 2005; Meadus et al., 2010). As with flaxseed, we have demonstrated that feeding canola to goats can lead toward an increased level of Omega-3 fatty acid (18:3) and therefore lead to the production of a heart healthy meat. Production of Omega-Chevon after flaxseed and canola feed supplementation to meat goats has not been elucidated. Therefore the objective of this study was to determine whether meat goat diets supplemented with canola and flaxseed result in an enhanced Omega goat meat (Omega-Chevon).

2. Materials and Methods

2.1 Experimental Animals and Feed Preparation

2.1.1 Animals

Pure bred meat goats (Kiko, Spanish, and Myotonic) aged 6 months old, male (15) and female (15) were housed in individual pens line with pine shavings. Each pen contained a time controlled automatic feeder attached to the wall. Hay racks were placed at the front of each pen. Drinking water and mineral blocks were accessible at all times. All animal handling and experimental procedures were approved by the Institutional Animal Care and Use Committee in accordance with the Animal Welfare Act.

2.1.2 Flaxseed and Canola (Omega 3-Sources) Diets and Preparation

Canola and flaxseed (York cultivar) seeds were roughly ground for meat goat feeding experiments. Proximate analysis was conducted on feed samples before formulation of the diet (Table 1). Diets were formulated using Winfeed 2.8 automatic ration formulation software.

Table 1. Composition of Canola and Flaxseed Supplemented Diets

Ingredient	Control	Flaxseed Diet	Canola Diet
Cracked Corn (75.11%)	+	+	+
Ground Soybean Meal (18.8%)	+	+	+
Feed Lime (1.88%)	+	+	+

Decoxx (0.47%)	+	+	+
Ammonium Chloride (0.94%)	+	+	+
Dried Molasses (2.8%)	+	+	+
Timothy Hay (*Ad libitum*)	+	+	+
Mineral Block (Commercial)	+	+	+
Flaxseed (6%)	-	+	-
Canola (6%)	-	-	+

Table 2. Proximate Analysis of Feed Components Fed to Meat Goats

(%)	Ash	Moisture	Crude Fat	Protein	ADF	NDF	Crude fiber	Oil
Corn Soy Bean Meal	**2.81**	**10.50**	**6.21**	**14.32**	**4.57**	**12.11**	**2.38**	**-**
Flaxseed	3.2971	0.0002	-	19.8933	29.1410	39.3989	18.8956	37.980
Canola	3.8968	0.0004	-	22.3817	32.2340	36.9819	20.2830	40.904
Timothy Hay	**5.60**	**7.70**	**4.08**	**8.25**	**37.48**	**60.53**	**35.13**	**-**

2.2 Omega-3 Feeding Trial

Ground flaxseed and canola was supplemented at 6% of the diet, and fed to 6 month old pure bred pasture fed meat goats for 90 days. Animals were fed one pound of each diet per head per day using time controlled automatic feeders (Figure 1) and Timothy hay and water *Ad libitum*. Mineral blocks were provided in each stall. Refusal was measured to determine how much they consumed. The control group received the normal diet during the course of the study. A seven day diet adaptation period was observed before data collection commenced.

2.3 Sample Collection

Blood samples (whole and serum) were collected before adaptation, at the beginning of the adaptation period and at time intervals (30 days each) after the 90 day feeding period, animals were sacrificed. The hind legs of each animal, including liver and intestinal samples (for further molecular analysis), were harvested and stored on ice. Meat fatty acid profile was determined. All fatty acid profile analyses were conducted in the Common Biochemical Lab at Virginia State University.

2.4 Oil Extraction and Fatty Acid and Methyl Ester (FAME) Analysis of Goat Meat

Goat meat samples were freeze dried and ground using an A11 S1 Mill (Colonial Scientific). The FAME preparation and analysis was conducted according to a previously published method (Bhardwaj & Hamama, 2000; Dahmer ML, Fleming PD, Collins GB, & DF, 1989). The oil was extracted in three rounds from 1 g ground freeze dried goat meat at room temperature by homogenization and centrifugation. The three extractions were pooled. The lipid layer was separated via the standard hexane:

methanol method. Percent oil was calculated on a g/100 g dry matter basis measured gravimetrically, vacuum dried and stored under N_2 at -10^{o}C until further analysis.

2.4.1 FAME Analysis

Fatty Acid Methyl Esters (FAME) were prepared using the acid-catalyzed transesterification method (Bhardwaj HL & Hamama, 2000; Dahmer ML et al., 1989). In brief, samples were vortexed with a 2 ml 1/100 sulfuric acid; methanol mixture with teflon derived boiling chips. Samples were then heated at 90^{o}C until only 0.5 ml residual was evident. Samples were allowed to cool to room temperature, to which 1 ml of hexane and distilled water was sequentially added. After vortexing, the upper hexane layer (FAME) was dried over anhydrous sodium sulphate. The hexane phase containing FAME was stored under N_2 at 0^{o}C and analyzed by gas chromatography (Vista 6000 GC). Analyses of FAME were carried out using a previously published method (Bhardwaj HL, 2003). Briefly, a Supelco Wax 10 capillary column (25 m, 0.25 mm i.d. and 0.25 lm film thickness, Supelco Wax,) with flame ionization detection was used to determine relative concentrations of detectable fatty acids. Peaks were identified using FAME retention and internal standards (C17:0) for quantification. Fatty acid concentration was calculated as a percentage (w/w) of total fatty acids.

3. Statistical Analysis

All data were analyzed using the General Linear Model procedure of SAS. Duncan Multiple comparisons test was used to determine differences between means. Breed, Gender and treatment interaction effects were analyzed using LS MEANS with Nelson adjustment. Means were considered significant at the 5% level of probability.

4. Results and Discussion

4.1 Animal Palatability, Weight Gain and Health Response

Goats were supplemented with ground canola and flaxseed at 6% of the normal diet. Figure 1 shows goats consuming flax and canola supplemented diets. The automated feeding apparatus shown was purchased and modified to include the extended arms pointing downward to the feed troughs. This allowed for a more accurate deposition of the designated amount of feed, and easy access for the goats consuming it.

Figure 1. Meat Goats Consuming Flaxseed and Canola Supplemented Feed

Overall 9/10 meat goats consumed flaxseed with no refusal and 10/10 ate canola with no refusal. Over the 90 day period of canola and flax consumption, goats steadily gained an average of 4.5 lbs every 30 days (Figure 2). Therefore feeding flax and canola supplemented diets did not have any adverse effect on weight gain.

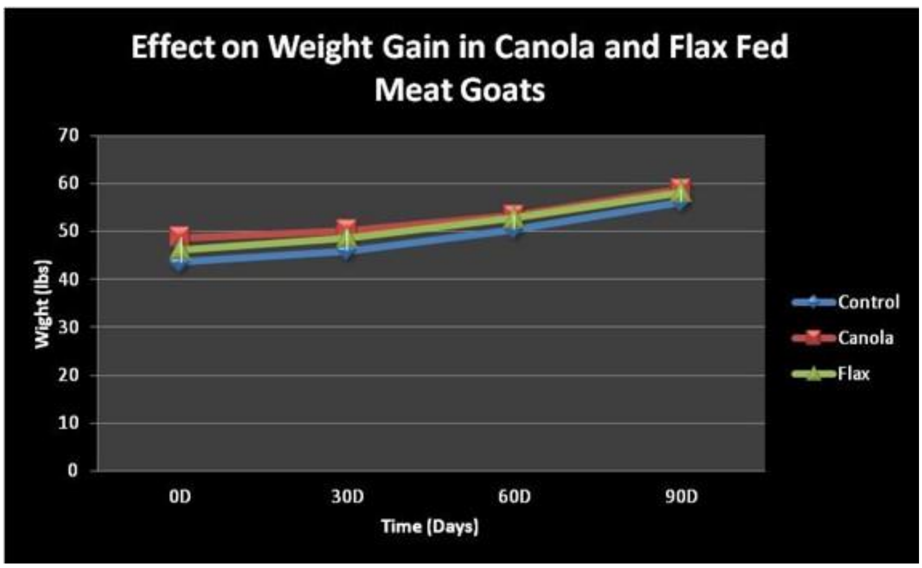

Figure 2. Effect on Weight Gain in Canola and Flaxseed Fed Meat Goats

Animals remained healthy overall with monitoring of blood micro-hematocrits (Figure 3) and parasite load via Fecal Egg Counts (FEC) (Figure 4) and FAMACHA eye color charts (data not shown). Goats were held in feeding pens and as expected remained with FEC (0-600 eggs/g feces) below a clinically treatable level. There were no palatability, average daily gain, or general health issues in meat goats fed canola and flaxseed supplemented feed.

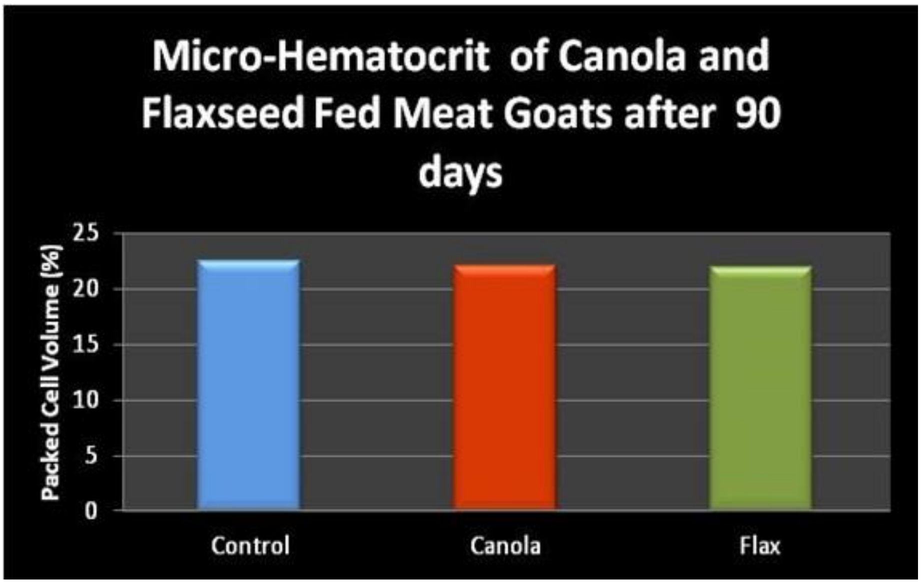

Figure 3. Micro-Hematocrit of Canola and Flaxseed Fed Meat Goats after 90 days

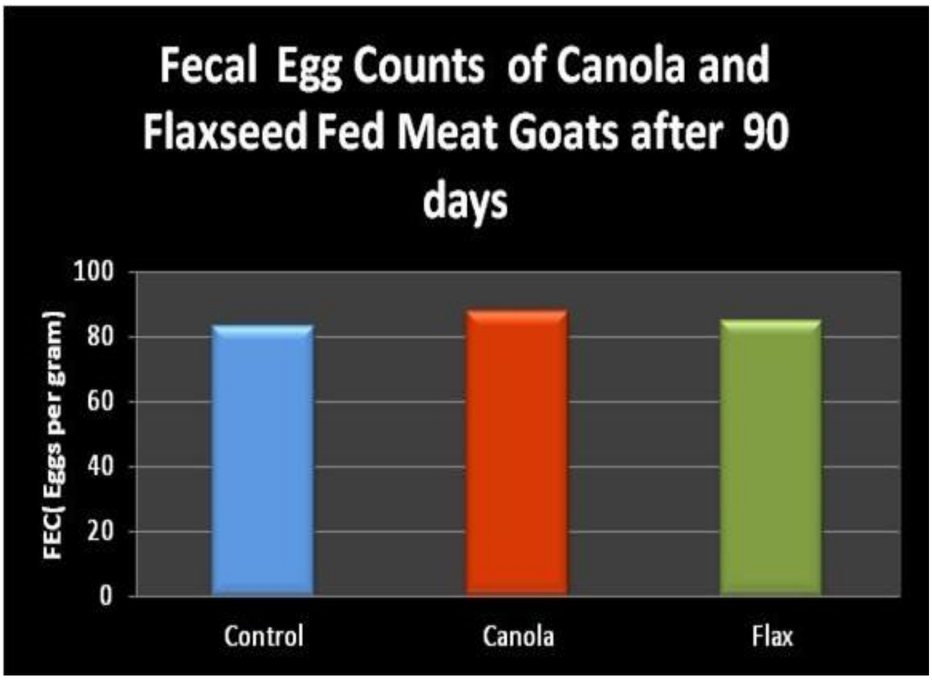

Figure 4. Fecal Egg Counts of Canola and Flaxseed Fed Meat Goats after 90 days

4.2 Omega 3, 6, 9 in Chevon from Flaxseed and Canola Fed Meat Goats

Overall, Chevon from meat goats fed canola and flaxseed had significant (P<0.05) increase in *Omega* 3, 6 and 9 fatty acids, compared to the control diet (Figures 5, 6, 7). However, Chevon from goats fed flaxseed supplemented diets had a marked increase (P<0.05) in *Omega* 3, 6, and 9 FA compared to those fed control and canola supplemented diets. Flaxseed fed goats showed a 57% increase in C18:3 and a 23% increase in Canola fed goats. There was a 30% increase in C22:6 (DHA) in flaxseed fed goats and a 15% increase in DHA in canola fed goats compared to control diets (Figure 5).

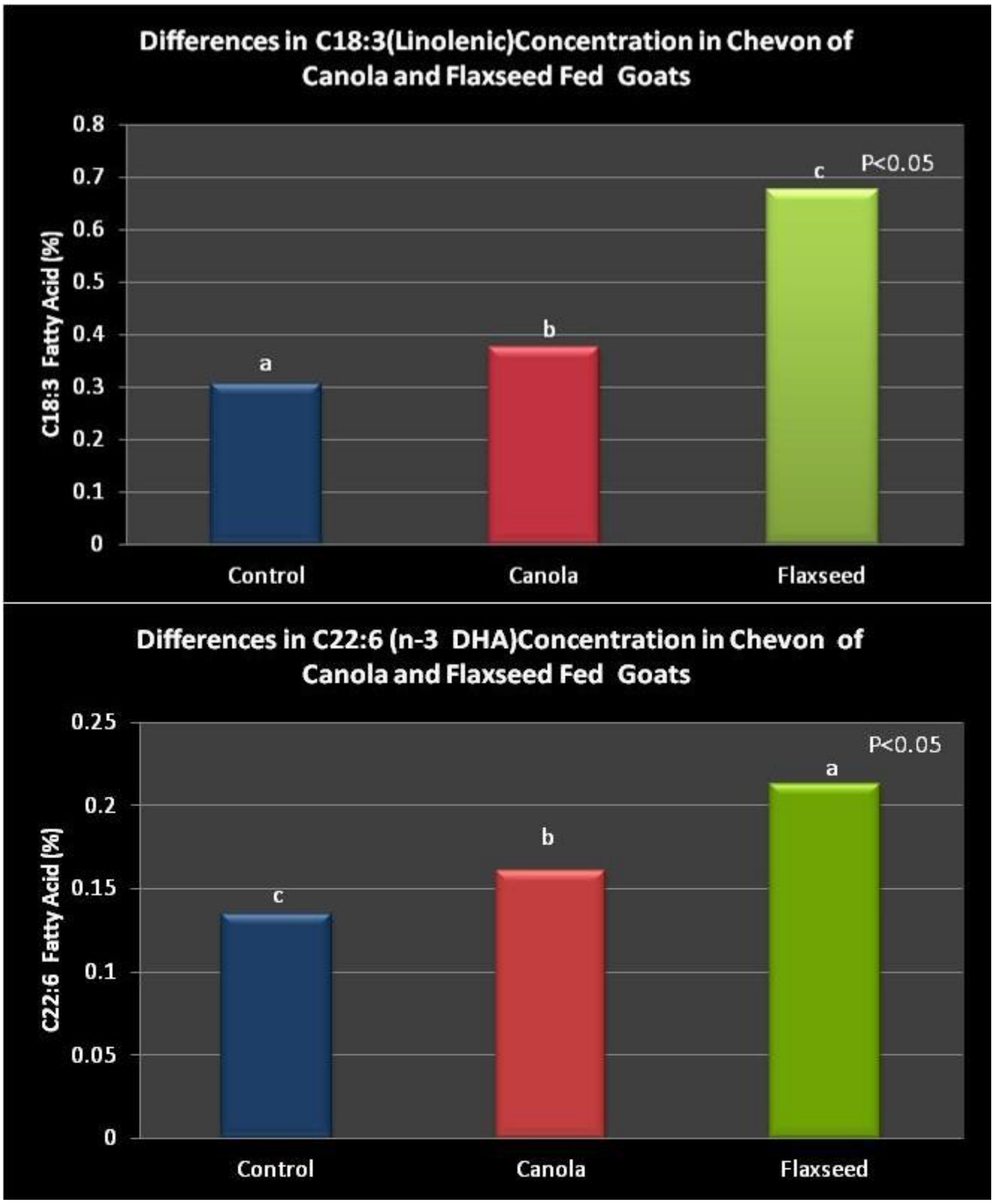

Figure 5. Differences in Omega-3 Fatty Acids in Chevon of Canola and Flaxseed Fed Meat Goats

Note. a, b, Means with different letters differ (P<0.05).

Although both flaxseed and canola fed goats increased C18:2 (*Omega*-6) by 27%, there was no significant increase in C20:4 (Arachidonic acid) (Figure 6). This was a good indication with regard to the *Omega* 3:6 ratio in the meat, as an imbalance of *Omega* 6 has been attributed to higher incidence of CVD.

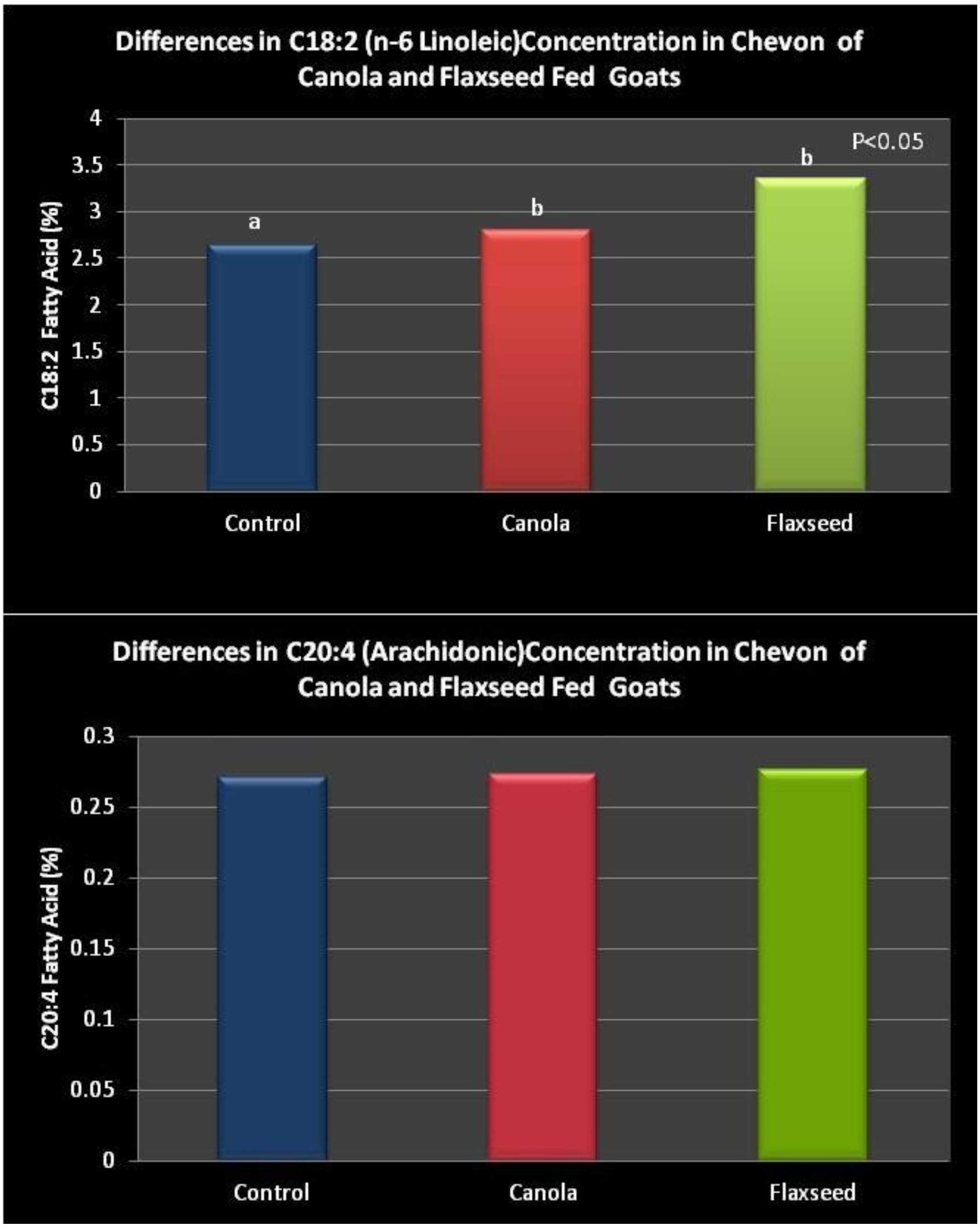

Figure 6. Differences in Omega-6 Fatty Acids in Chevon of Canola and Flaxseed Fed Meat Goats

Note. a, b, Means with different letters differ (P<0.05).

Within the classification of *Omega* 9 fatty acids, there was no significant change in C18:1 in Chevon from flaxseed and canola fed goats compared to control, though a slight difference in canola vs flaxseed fed goats. There was only a 2.5% increase in C22:1 (erucic) in Chevon from both flaxseed and canola fed goats. This was a good indication, as erucic acid is not highly favorable in the diet, since known to cause gastric disturbance. On the other hand there was a 35% increase in C20:1 in Chevon from both flaxseed and canola fed goats (Figure 7).

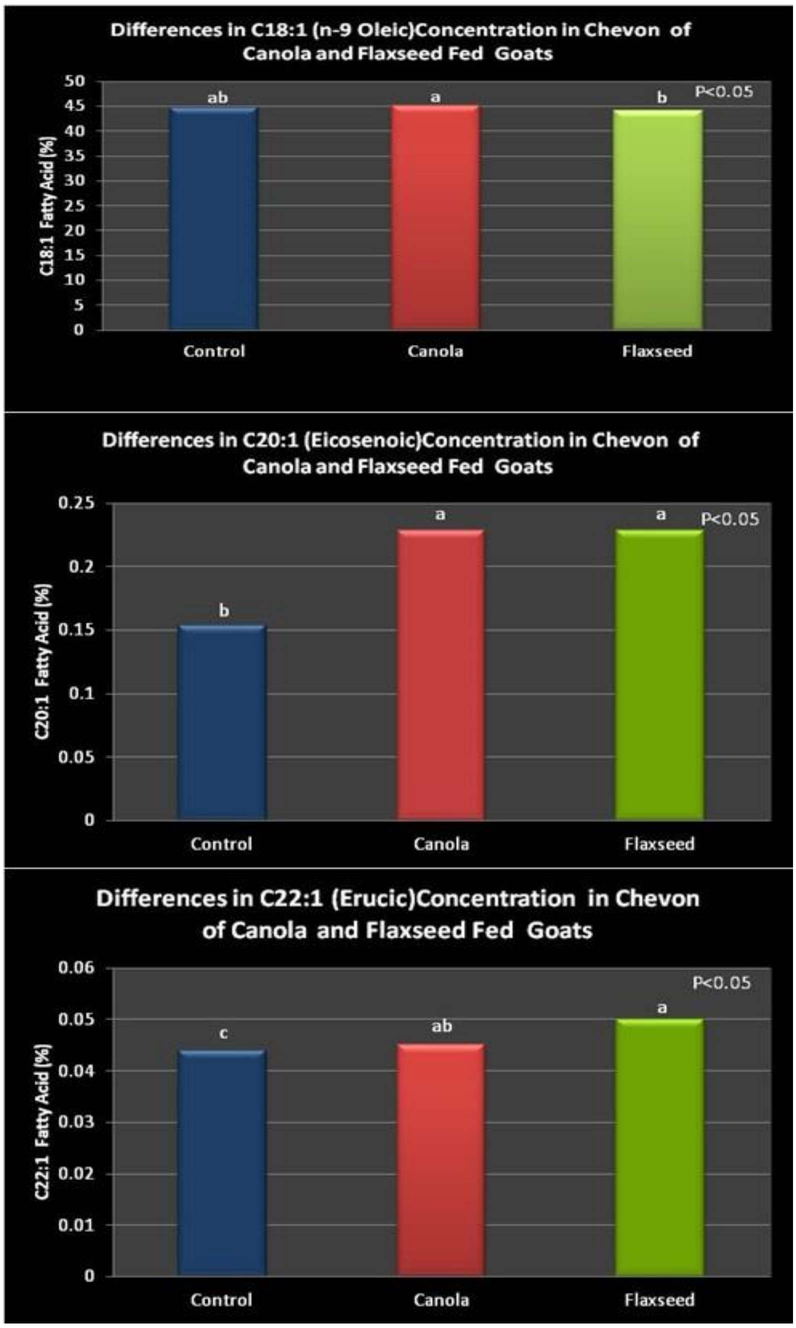

Figure 7. Differences in Omega-9 Fatty Acids in Chevon of Canola and Flaxseed Fed Meat Goats

Note. a, b, Means with different letters differ (P<0.05).

Breed effect data analysis showed that Chevon from Spanish (Figures 8, 9) and Myotonic (11, 12) goats fed flaxseed had increased (P<0.05) *Omega*, 3, and 6 FA compared to control. However, C18:1 (*Omega* 9) FA was higher in Chevon from Myotonic goats vs. Spanish goats, whereas Chevon from both Spanish and Myotonic goats were higher (P<0.05) in C20:1 (*Omega* 9) FA compared to Chevon from those fed the control diet (Figures 10, 13).

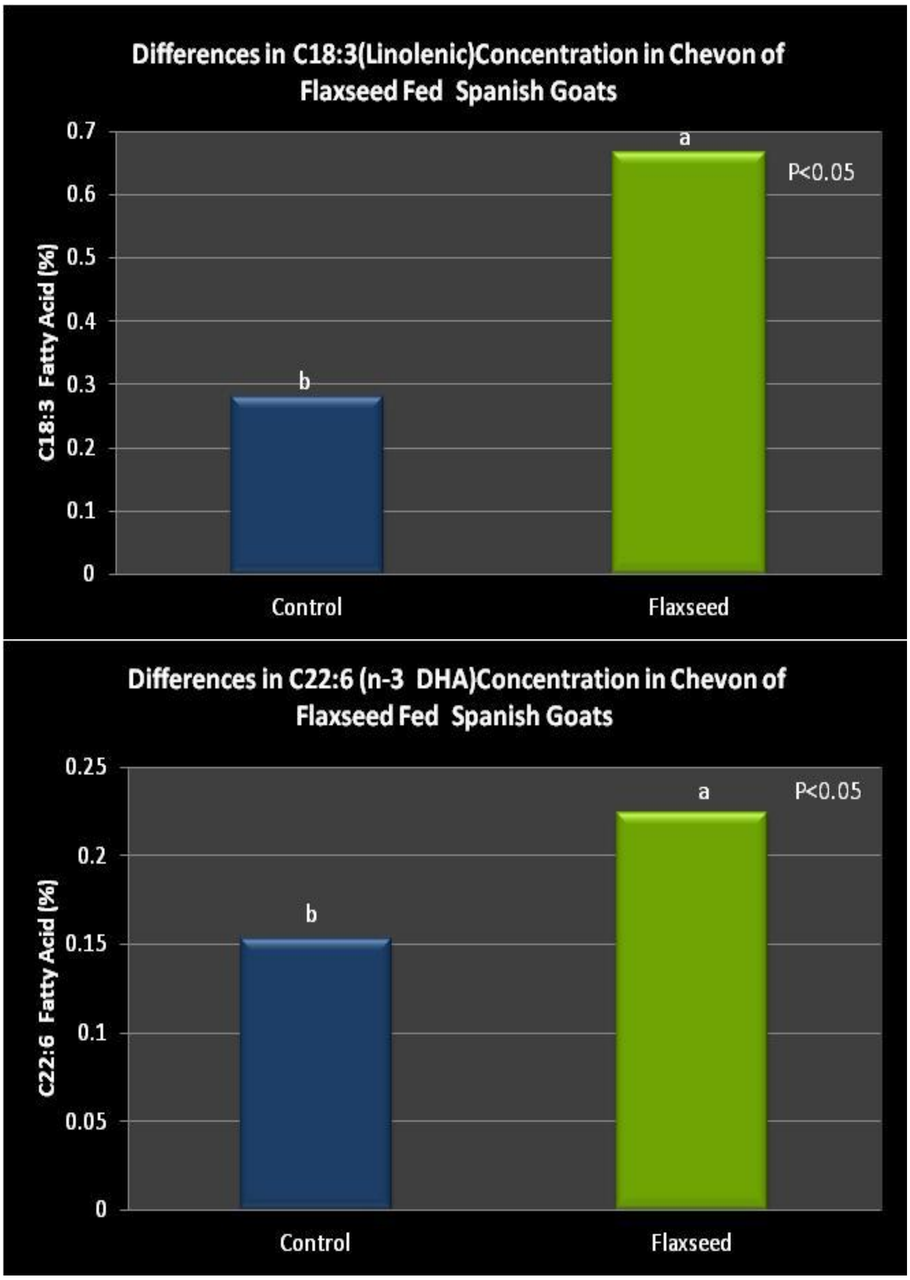

Figure 8. Differences in Omega-3 Fatty Acids in Chevon of Canola and Flaxseed Fed Spanish Goats

Note. a, b, Means with different letters differ (P<0.05).

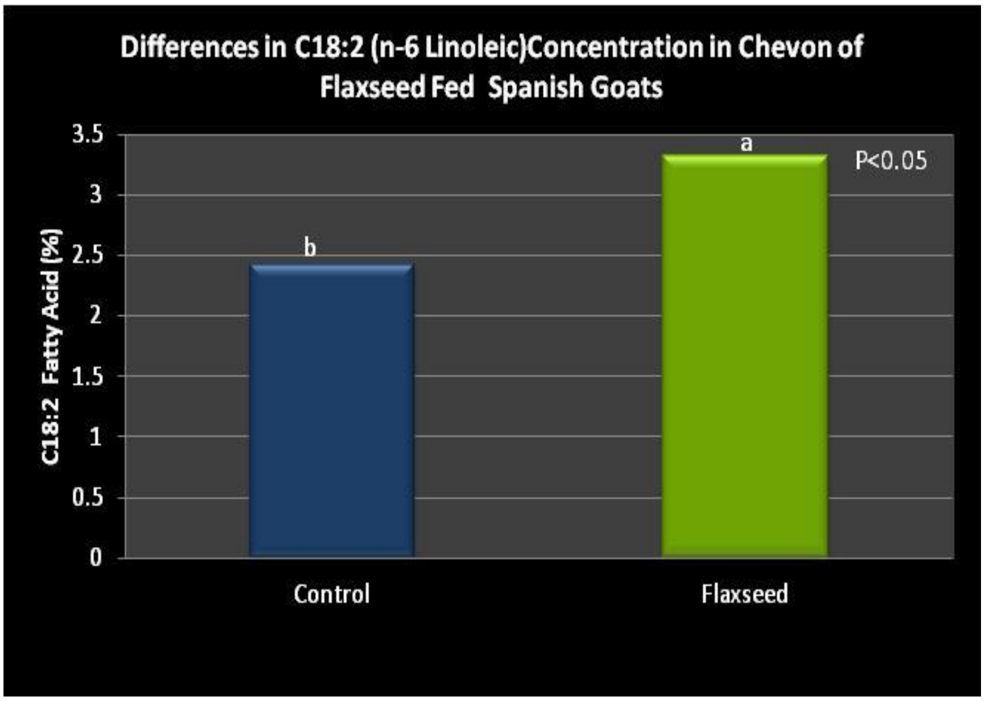

Figure 9. Differences in Omega-6 Fatty Acids in Chevon of Canola and Flaxseed Fed Spanish Goats

Note. a, b, Means with different letters differ (P<0.05).

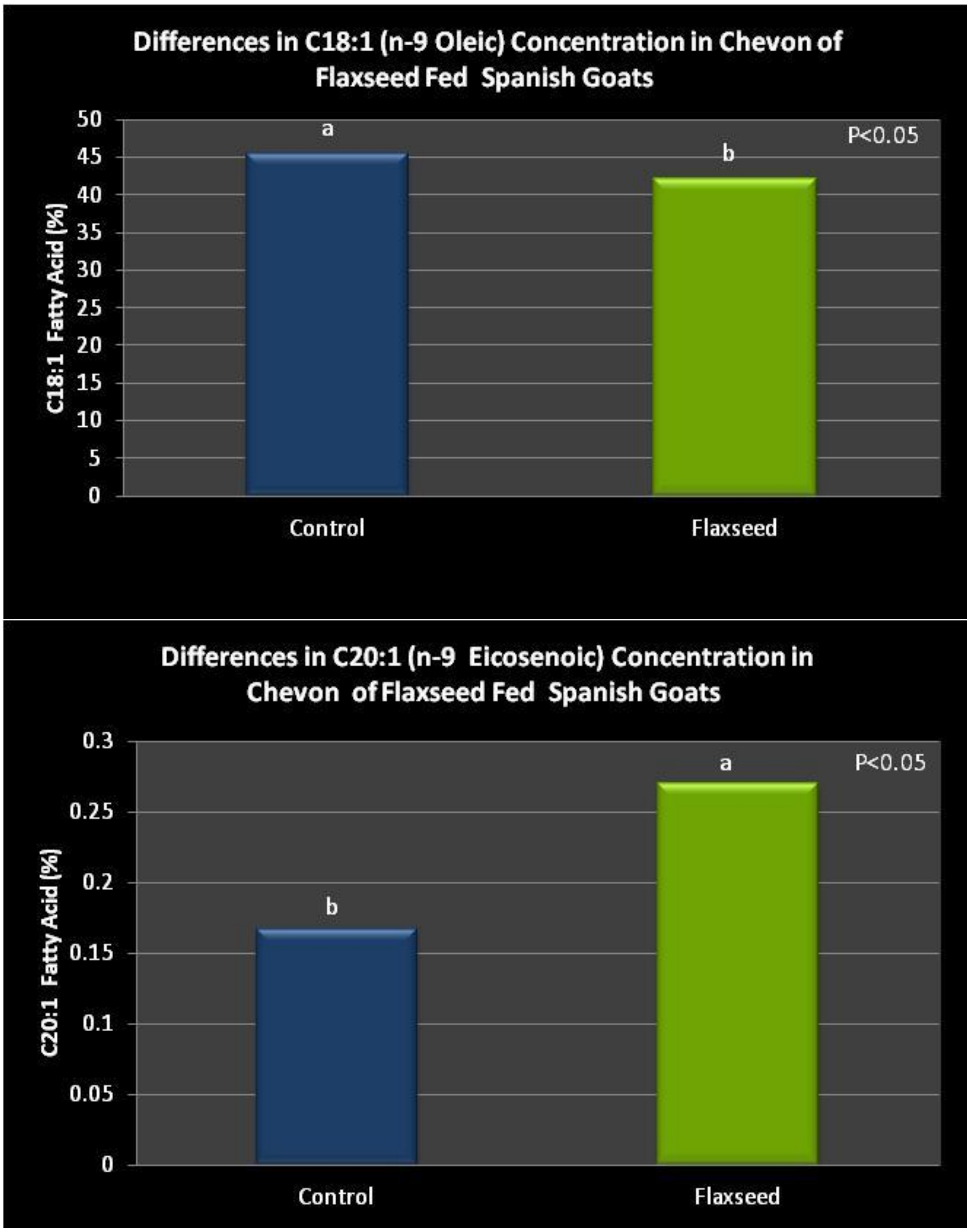

Figure 10. Differences in Omega-9 Fatty Acids in Chevon of Canola and Flaxseed Fed Spanish Goats

Note. a, b, Means with different letters differ (P<0.05).

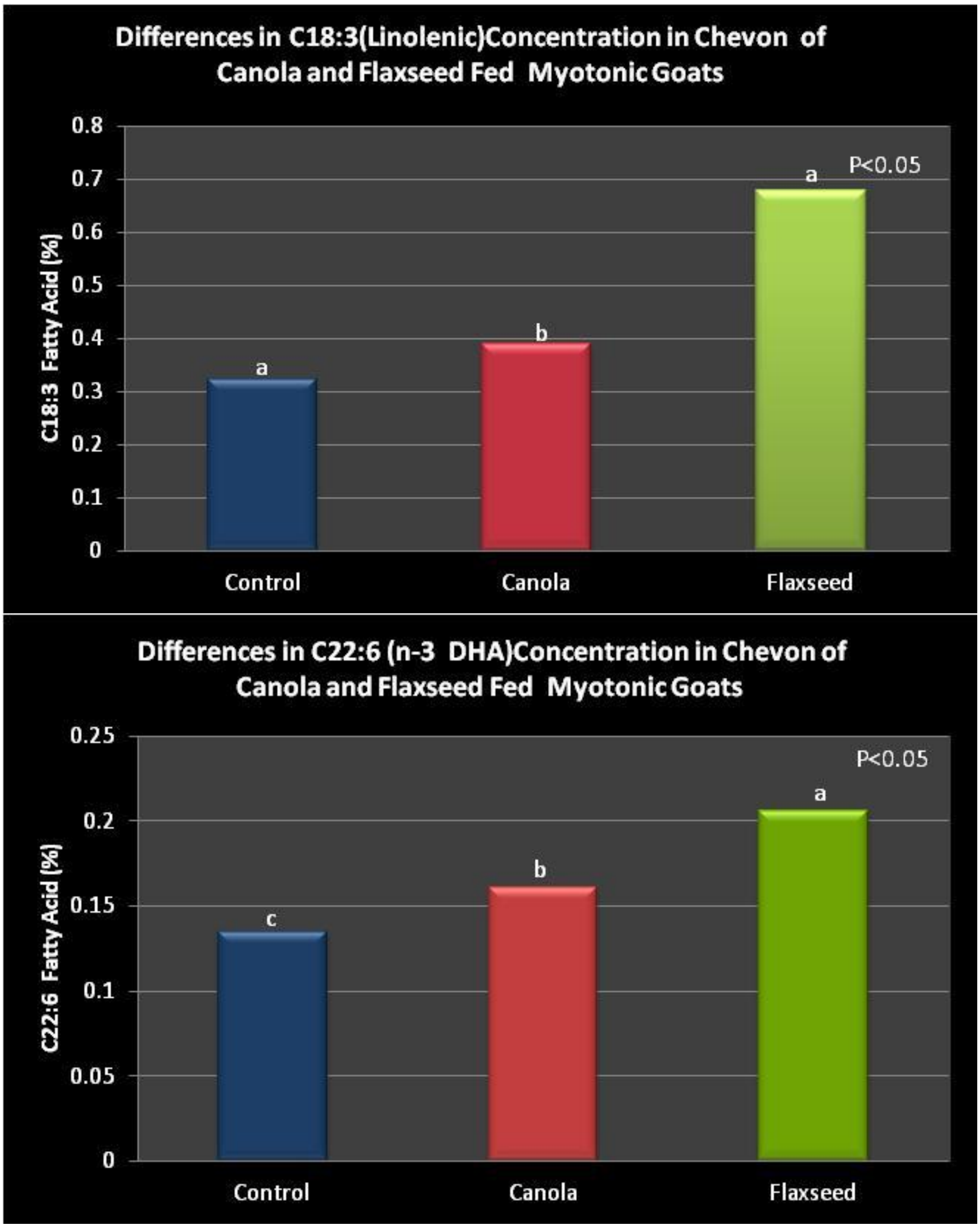

Figure 11. Differences in Omega-3 Fatty Acids in Chevon of Flaxseed Fed Myotonic Goats

Note. a, b, Means with different letters differ (P<0.05).

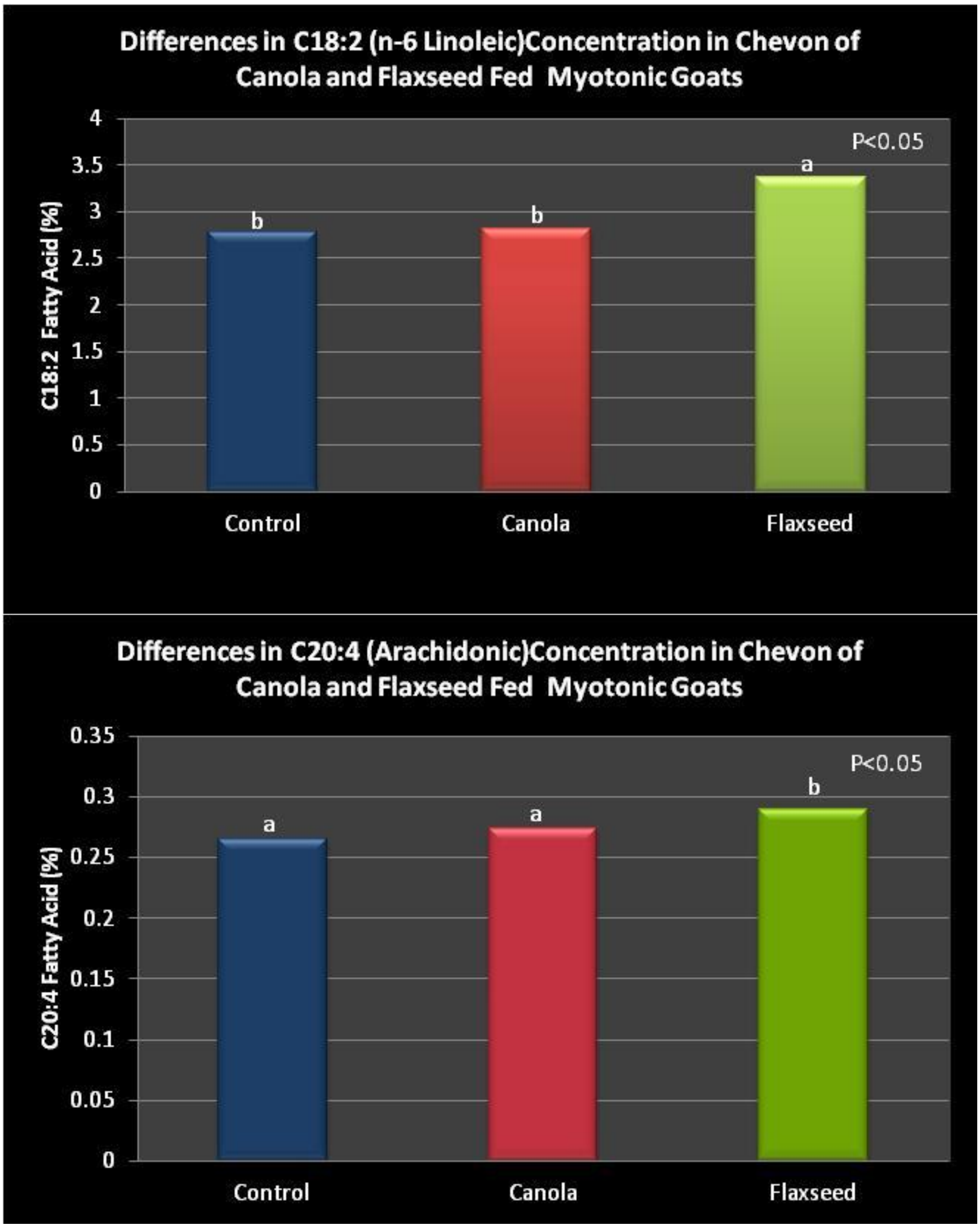

Figure 12. Differences in Omega-6 Fatty Acids in Chevon of Flaxseed Fed Myotonic Goats

Note. a, b, Means with different letters differ (P<0.05).

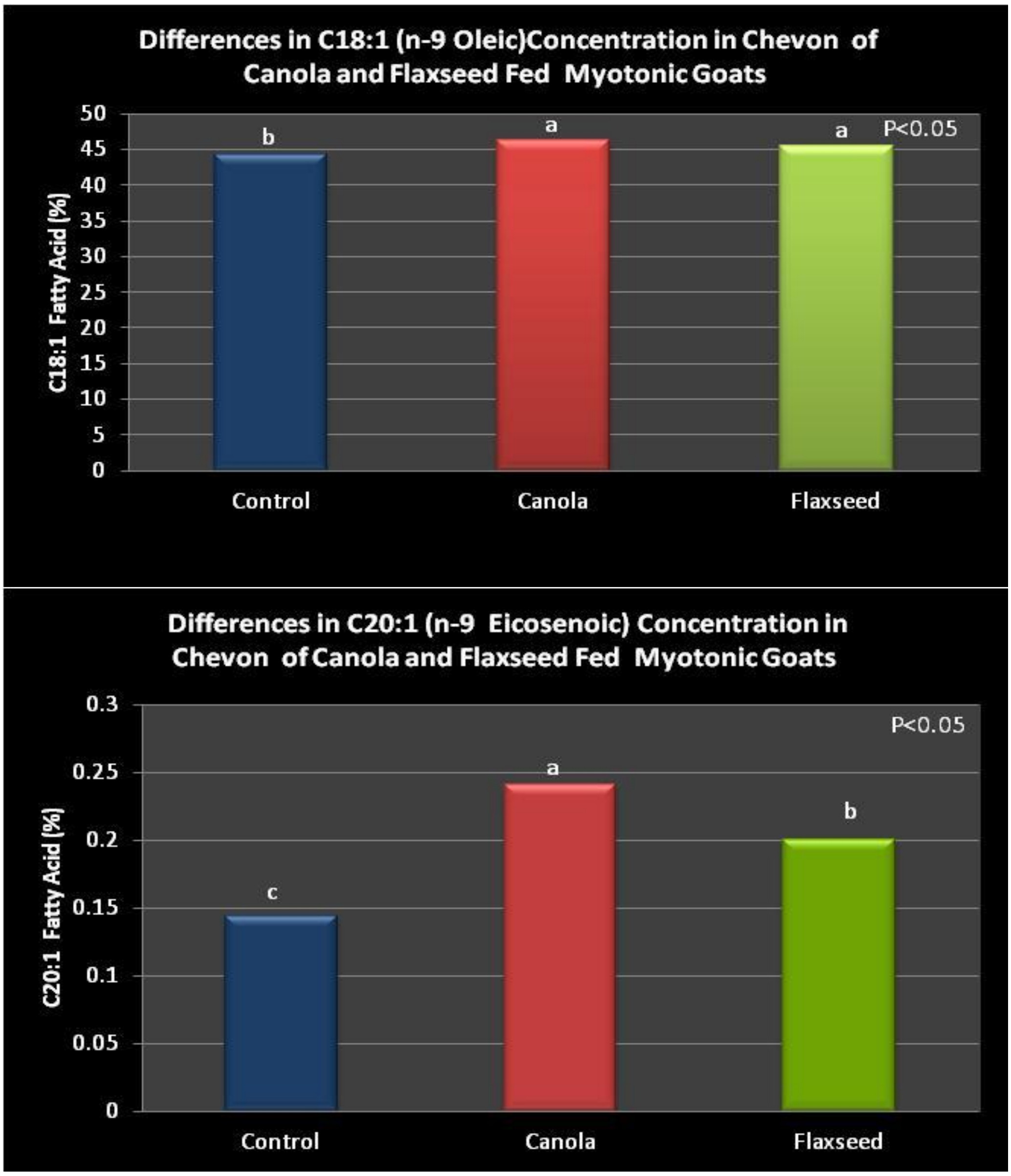

Figure 13. Differences in Omega-9 Fatty Acids in Chevon of Flaxseed Fed Myotonic Goats

Note. a, b, Means with different letters differ (P<0.05).

The observation that consumption of *Omega* 3, 6, 9 rich flaxseed and canola supplemented feed by meat goats influenced the *Omega* 3, 6, 9 composition of the meat in the face of the rumen microbe exposure, is an indication that these unsaturated fatty acids were able to evade complete bio-hydrogenation by the rumen microbes and elucidate an effect on the *Omega* content of the resulting meat (*Omega*-Chevon). The efficiency of this conversion is yet to be established in meat goats. This research has both meat goat industry and human health implications. Chevon is one of the most consumed red meats worldwide. It is one of the leanest meats when compared to beef, chicken, pork and lamb. Consumption of an *omega*-enhanced red meat like *Omega*-chevon can impact the incidence of heart disease in humans and provide an alternative red meat.

5. Conclusion

Omega-Chevon can be successfully produced from meat goats fed flaxseed and canola supplemented diets. This holds great human health implication for marketing *Omega*-Chevon as a heart healthy red meat for human consumption in the hopes of controlling CVD and obesity. Future research is needed to determine whether CVD predisposed individuals consuming *Omega*-Chevon would result in a reduction in health parameters that point to CVD.

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