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FATTY ACID COMPOSITION OF GROWING KIKO X SPANISH CROSSBRED INTACT MALE GOATS FED VARYING LEVELS OF PEANUT SKINS

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Abstract

The objective was to evaluate the effects of feeding peanut skins (PS) on fatty acid profile of goat meat. The diets used contained 0, 10, 20, and 30% of PS. After 92 days, longissimus muscle (LM), mesenteric adipose (MA), and subcutaneous (SA) tissue samples were analyzed for fatty acid profile. Eighteen (18), 21, and 21 fatty acids were detected in LM, MS and SC adipose tissues, respectively. No changes were detected in the fatty acid profile, but C18:0 increased linearly in LM ($p < 0.05$) with increasing level of PS whereas C18:1 decreased in the similar manner ($p = 0.05$). Total saturated fatty acid and monounsaturated fatty acid percentage increased linearly ($p < 0.05$) in LM fat, but polyunsaturated fatty acids were not different ($p > 0.05$) among treatments. The results showed that the fatty acid composition of goat carcass can be altered with the dietary addition of PS.

Keywords: Meat Goats, Peanut Skins, Fatty Acids

Introduction

Goats utilize a variety of forages, browse, and feed on weeds and brushes more efficiently than other ruminants. However, supplementation is needed during certain times of the year, such as in late summer or time of hay feeding, especially in the Southeastern U.S. Peanut skins (PS) are one of the locally available by-products of the peanut blanching process for use as a supplemental feed. Also, the demand for goat meat has been steadily increasing in the U.S. for the past two to three decades, and this has led to imports from abroad, mainly from Australia. The influx of immigrants from nations who are frequent consumers of goat meat as well as the growing desire for healthier diets are the driving forces behind the increasing demand for goat meat (Gipson 1999; Geisler, 2011). In order to increase meat goat production in the U.S. in a sustainable manner, it is important to include the agricultural by-products, such as PS, in feed for these small ruminants. However, consumers have become very conscious about healthy eating habits; hence, it is important to determine the carcass quality and quality of fatty acid content when feeding PS before recommending them as a suitable supplemental feed for meat goats.

The three leading states in peanut production are Texas, Georgia, and Alabama. Approximately 20,000 to 30,000 metric tons of peanut skins are produced in the U.S. annually and most of it is used as animal feed (Abdelrahim et al., 2008). The typical nutrient contents of PS are 17% protein, 25% fat, and 65% total digestible nutrients (TDN). The feeding value of PS has been evaluated for dairy (Utley et al., 1993) and beef cattle (Hill, 2002). Because of high levels of tannins (up to 21%), the proteins are poorly digested and its energy value is low despite high fat content. That is why its inclusion rates are low in cattle. However, goats have been shown to be especially adept at handling moderately high levels of tannins in their diet. The peanut skins can also serve as lubricant to pelleting bermudagrass. The dry matter intake and total digestible

nutrient values were greater for pellet diet containing 10% peanut skins than the bermudagrass pellet diet without added peanut skins (Utley et al., 1993).

The main disadvantages with PS as a potential feedstuff for goats are its high level of fat content and low bulk density (very fluffy). The higher inclusion of PS in the diets for goat will increase the energy density of the diets but may alter the pattern of lipid deposition and fatty acid profile in goat muscles. The fat composition of peanut fat (oil) contains 11.5% C16:0, 3% C18:0, 53% C18:1, and 26% C18:2; the iodine value is 90 (Palmquist, 1988). Increases in muscle content of omega-3 fatty acid (C18:3n-3) of 1-3 fold have been obtained from supplementation with oil, or oilseeds in sheep (Sinclair, 2007). In general, dietary fats are hydrolyzed into individual fatty acids of which polyunsaturated fatty acids are hydrogenated by the rumen bacteria into saturated fatty acids. This is the reason why most of the fatty acids in ruminant lipids are saturated fatty acids. The consumption of saturated fatty acids is linked to increased incidence of coronary heart disease (Givens, 2005). Goat fat is reported to be lower in saturated fats compared to other red meats. However, there has been no research conducted regarding the feeding of PS to meat goats and its impact on fatty acid quality and composition. Therefore, the objective of this study was to evaluate the effects of feeding PS on fatty acid profile of goat meat. The hypothesis of the experiment is that up to 30% of PS can be added in diets for use in meat goats.

Literature Review

The peanut skins (PS) contain up to 24% of highly digestible oil (Utley and Hellwig, 1985). Due to its high oil content, high inclusion rates of PS in diets for animals are prohibitive. There is another anti-nutritive factor that prohibits higher inclusion rates; the presence of condensed tannins (CT) in PS (Hill, 2002). The CT binds to proteins making them less available for animals in the rumen, but enhances the availability of undegradable proteins and essential amino acids in ruminants in abomasum fed diets entirely of fresh forages. The CT is available in many leaves and forages used as animal feeds but they vary considerably in their chemical structures depending on types of forages (Barry and McNabb, 1999).

Beef cattle are the major livestock species fed PS, but only 10% of PS can be fed to growing-finishing cattle in their total diets. Since goats are capable of handling higher levels of condensed tannins in their diets, the PS have the potential to be used as goat feeds. However, the higher oil content in PS consisting of mainly unsaturated fatty acids can be of concern. To date, there are no studies conducted on the effects of feeding PS on growth performance and the fatty acid composition on goat carcass. Goat meat is considered relatively lean and its fatty acid composition has received considerable attention around the world (Owen and Norman, 1977).

Fat content of meat, however, varies widely according to various factors such as age, breed, weight at slaughter, and physiological condition (Madruga et al., 2001). The fatty acid composition of ruminant carcass is less affected by dietary lipid composition (Rhee et al., 2000). The main reason is ruminal conversion (saturation) of dietary unsaturated fatty acids to saturated fatty acids (biohydrogenation). The pathway for rumen bacterial biohydrogenation of linoleic acid (LA) involves three steps. The first step, yielding cis-9, trans-11 conjugated linoleic acid (CLA), is catalyzed by isomerase. In the second step, CLA is hydrogenated to produce trans-11 octadecanoic acid (vaccenic acid; VA). The Final step is hydrogenation of VA to produce stearic acid (SA). This pathway was confirmed by studies involving incubation of unsaturated fatty

acids with rumen contents in *in vivo* and *in vitro* studies (Dawson and Kemp, 1970). The microbial biohydrogenation is responsible for the high degree of saturation attained in ruminant fats although biohydrogenation contributes little, as a hydrogen sink; only 1 to 2% of metabolic hydrogen (Czerkawski and Clapperton, 1984). This was revealed with Angus steers ranging in weight from 290 to 376 kg to study the relationship of rumen protozoa to lipid metabolism when the effect of feeding unsaturated fats (Clemens et al., 1974). The evolutionary role of rumen microbes as regards to biohydrogenation is to protect rumen microbes from toxic effects of UFAs, although

However, several researchers have shown that dietary fatty acid composition differences can result in differences in carcass fatty acid composition (Rhee et al., 2000). In ruminants, dietary fatty acids can affect rumen fermentation pattern which in turn can affect the fatty acid composition of milk. The C15:0 is one of the main odd-and branched-chain fatty acids (OBCFA) in milk of dairy cows, largely derived from bacteria leaving the rumen, therefore, there is an increasing interest in OBCFA as potential diagnostic tools of rumen function (e.g., rumen fermentation pattern, bacterial nitrogen) (Casey et al., 2003; Vlaeminck et al., 2004). The fat extracts from the muscles of range goats (raised in rangeland without any feed supplements) were more saturated than that of goats fed a grain-based diet. The total saturated fatty acids were reduced by feeding canola seed and the reduction was mainly in palmitic acid. The palmitic acid (C16:0) is the third most abundant fatty acid in subcutaneous adipose (SA) tissue in growing ram lambs (Lough et al., 1992). Palmitic acid is the primary product of *de novo lipogenesis* (C16:0), a saturated fatty acid (Murray et al., 1996). Kemp et al. (1981) reported that lambs fed on drylot conditions with either a 13% protein creep or a 16% protein creep feeds, showed linear decrease for C14:0 and C16:0 and linear increase for C18:0 indicating a shift toward longer chain fats. Similarly, male alpine goats fed 70% concentrate mixture and 30% wheat bran had fat composition altered with decrease in saturated fats for goat kids ranging from 12 to 19 kg body weight (BW) (Manfredini et al., 1998). They showed that intramuscular fat composition in goat kids varied because of differences in growth rates and the composition of feed intake. This was observed due to low proportions of short and medium chain fatty acids and high concentrations of C18:0 fatty acids in post-weaning diets fed to goat kids (Sauvant et al., 1979).

Consequently, there has been increased interest amongst animal and food scientists to reduce or manipulate the fatty acid composition of meat through dietary means (Wood et al., 2003) so livestock producers can produce red meat products that are low in saturated fats, cholesterol, and also, to reduce the risk of atherosclerosis (Lough et al., 1992). The longer-chain fatty acids especially polyunsaturated fatty acids (PUFAs) of both the n-3 and n-6 series (and their ratios are important components of tissue lipids, especially cell membrane phospholipids. The deficiencies of these fatty acids in animal diets are related to easily observed pathologies such as retarded growth, reproductive failures, and changes in many organs including the skin, liver, and kidneys (Banskalieva, 1996) but the deficiency state can be prevented at any age by the provision of adequate amounts of n-3 fatty acids in the diet in primates (Neuringer et al., 1988). The n-3 fatty acids play a special role in nerve tissues. However, the excess consumption of dietary fats impacts the level of lipoproteins that carry cholesterol in the blood especially low-density lipoprotein that can be deposited in the arteries leading to coronary heart diseases in humans (Mensink and Katan, 1992).

Some researchers argue that not only the type of fat but the PUFA/SFA (saturated fatty acid) ratio as a measure of the propensity of the diet to influence the incidence of coronary heart disease is a better indicator of atherogenicity and thrombogenicity (Ulbricht and Southgate, 1991). The fatty acid composition of the carcass depends on the location of the carcass. Banskalieva (1996) conducted two experiments with male lambs and hoggets (castrated vs. uncastrated) of the semi-fine fleeced breed with different levels of dietary protein for 120 days on weaned animals of 45 days age. The internal fats were more saturated than the SA fat but physiological condition did not induce marked changes in fatty acid composition. Park and Washington (1993) also found higher levels of saturated fatty acids (SFAs) in mesenteric adipose (MA) tissues (41.1% in liver, 42.8% in kidney, and 40.4% in heart compared to 36.5% in longissimus dorsi and 38.9% in biceps femoris for 5-month weaned doelings and bucks goat kids. The fat contents in internal, omental, mesenteric, perirenal and pelvic depots are more saturated than the subcutaneous and intramuscular depots because of gradient in body temperatures, which result in saturated fats with a higher melting point being deposited where the temperature is the highest (Sauvant et al., 1979).

Meat is the predominant source of fat in the diet for humans, and the fat type is an important health concern to consumers. Therefore, any dietary manipulations that can reduce fat content and the composition of carcass are desirable. Regardless of the dietary fat composition, oleic acid (C18:1) is more than two-third of the unsaturated fatty acids (UFAs) in mesenteric goat fats (Rhee et al., 2000). Madruga et al. (2001) showed that the goat carcass muscles contain mostly C18:1 (range 38-44%), C18:0 (23-25%), C16:0 (18-21%), and C18:2 (4-6%) based on fatty acid composition of muscles of native Brazilian goats slaughtered at various ages. These data demonstrate that the predominant fatty acids in edible goat meat by-product were C16:0, C18:1, and C18:0 accounting for about 90% of the total fatty acids (Madruga et al., 2007). They reported that cholesterol contents increased with age but other fatty acids not differ.

Mahgoub et al. (2002) reported that palmitic acid (C16:0), stearic acid (C18:0), and oleic acid (C18:1) acids comprised the major proportions of fatty acids in goats slaughtered at 11, 18, or 28 kg BW. The total was approximately 80% with oleic acid being the most abundant. Ninety-one percent of the total fatty acid was contributed by the C16:0 and C18 fatty acids being 31.6 and 58.5%, respectively. The stearic acid (C18:0) although a significant proportion of fatty acids does not elevate blood low-density lipoprotein(LDL) cholesterol levels because it is considered neutral fatty acid (Duckett and Pavan, 2007). Pratiwi et al. (2006) examined the effect of breed, slaughter weight and castration on fatty acid profiles in the longissimus thoracic muscles from Boer and Australian feral goats (mean of 180 days of age) fed a mixture of native pastures and Rhodes grass (*Chloris Guyana*) with access to grassy Lucerne hay and goat pellets. The fatty acid content of the longissimus thoracic muscles from both breeds were primarily of oleic acid (C18:1; 43.3 to 53.8%), followed by palmitic acid (22.5 to 27.9%), and stearic acid (10.7 to 18.1).

Cummins et al. (2008) examined the effects of varying levels of copper supplementation on fatty acid composition of muscle and adipose tissues of Boer X Spanish goat kids of 4 to 5 months old kids fed 70% concentrate and 30% hay and found that oleic acid was the major fatty acid in the longissimus muscle (41 to 46%). Banskalieva et al. (2000) pooled data from many trials for fatty acid composition of goat muscles with different feeding designs, breed, age, and anatomical

locations. The C18:1 value ranged from 28 to 51% of total lipids but cautions should be taken when comparing differences (Banskalieva et al., 2002). In sheep, fatty acid composition of muscles had approximately 27% C18:1 and 10 to 12% C18:2 when sixty Rambouillet ram lambs (32.4 kg BW) were fed safflower seeds (21% of the diet). The safflower seeds containing diets has abbot 15% C18:1 and 40% C18:2, respectively (Knott et al., 2010). Similar results were reported with finishing steers fed the whole oilseeds and white grease (Felton and Kerley, 2004) and with Friesian bulls fed olive cake pulp with limited amount of straw (Belibasakis et al., 1991). The fatty acid profiles of Moroccan goats raised either in the Argan forest with limited concentrate or completely indoors fed concentrate feeds had *longissimus dorsi* muscles with fatty acids C14:0 (16 to 22%), C18:0 (14 to 18%), and oleic acids (32 to 47%) (Bas et al., 2005).

Methodology

Experimental Setup

This experiment was conducted at the Caprine Research and Education Unit at Tuskegee University, George Washington Carver Agricultural Experiment Station, Tuskegee, Alabama, USA. The research protocols were approved by the Tuskegee University Animal Care and Use Committee. Goats were purchased from a local producer. Upon arrival, goats were dewormed with Cydectin (moxidectin @ 1mg/kg BW; Fort Dodge Animal Health, Fort Dodge, IA, USA), and vaccinated with *Clostridium perfringens* type C and D-Tetani Bacterin-Toxoid (Bayer Corp., Shawnee Mission, KS, USA). Twenty-four Kiko crossbred intact male goats (18.2 ± 1.41 kg initial BW and 4 to 5 months of age) were individually housed in 1.1m x 1.2 m pens with plastic-coated expanded metal floors. The goats were randomly assigned to one of four treatments (six goats/treatment) containing 47.3% Bermudagrass hay (BGH) plus 52.7% concentrate-containing PS with 0, 10, 20, and 30% of PS in total diet on a dry matter basis.

Diets provided or exceeded nutrient requirements for growing goats (NRC, 2007). Goats were adjusted to their individual diets for two weeks. Feed intake was monitored daily while goats were weighed every 4 weeks after a 4-hour withdrawal of feed and water. After 92 days, goats were weighed for two consecutive days, and were harvested to collect tissue samples from the longissimus muscle (LM), subcutaneous adipose (SA) tissue, and mesenteric adipose (MA) tissues for subsequent analysis of fatty acids. Chemical composition of composite samples of BGH, PS, and concentrate mixes were determined (AOAC, 1990). Percent condensed tannins were determined using Folin-Denis reagent by methods of AOAC (1984).

Sample Analysis

Fatty acids were extracted by using an organic solvent and separated by means of gas chromatography. Fatty acid methyl esters were prepared using the method of O'Fallon et al. (2007) with minor changes. Peak identification was carried out by comparing the peak retention times with those of two fatty acid methyl esters (FAME) standards, GLC-463 (Nu-Chek Prep, Elysian, MN, USA), and Supelco 37 FAME Mix (Supelco, Bellefonte, PA, USA). For the quantification of the FAMEs, the internal standard used was trinondecane (i.e., a triacylglycerol of C19:0, NU-Chek Prep, Elysian, MN, USA). The percent fatty acid of each sample was determined by dividing the total area by the adjusted area that contains only the fatty acid that is present in the sample.

Statistical Analysis

Fatty acid profile data were analyzed using the General Linear Model procedure of SAS (1998) as a completely randomized block design. The initial BW was used as a covariate for fatty acid data. The effects of varying levels of PS were tested by a polynomial regression using orthogonal contrast for equally spaced treatments (Steel et al., 1997). The differences among means were declared at $p < 0.05$ level of significance.

Results and Discussion

Chemical Composition

The chemical composition of composited concentrate mixes containing BGH and different amounts of PS is given in Table 1. The BGH used in the current study was better quality hay compared to the average BGH values reported to be 7.8% crude protein (CP), 76.6% neutral detergent fiber (NDF), and 49% total digestible nutrient (TDN) (NRC, 1996). The ether extract (EE) content of PS was 19.05%, which was lower than the published values that ranged from 24 to 30% (Hill, 2002; Uteley and Hellwig, 1985). However, the CP value was 22.7%, which was higher than the values reported by other researchers. For example, an average value of 15.5% CP was reported by Uteley et al. (1993). Similarly, the TDN value was much higher 87.7% compared to an average of 65% reported by Hill (2002). The discrepancy in nutritional values reported by other researchers may have resulted due to different peanut blanching processes used by different processing plants and the different methods of TDN calculation by different labs. However, nutritional values are generally consistent within a particular blanching plant.

Table 1. Chemical Composition of Concentrates Containing Different Amounts of Peanut Skins (PS), Bermuda Grass Hay (BGH) and PS fed to Kiko X Spanish Crossbred Intact Male Goat Kids¹.

Item	%, PS				BGH	PS
	0	10	20	30		
Dry Matter, %	86.9	87.8	88.2	88.1	87.8	91.2
Crude Protein, %	14.1	13.9	14.1	14.7	10.7	22.7
Ether Extract, %	0.88	3.35	6.37	9.1	2.25	19.05
Acid Detergent Fiber, %	42.2	39.6	41.5	42.3	32.5	32.7
Neutral Detergent Fiber, %	56.9	51.7	49.3	46	65.9	39.6
Non-fiber Carbohydrate, %	26.3	26.5	26	29.4	19.2	28.4
Total Digestible Nutrient, %	66.7	63.5	57.7	63	61.5	87.7
Ash, %	6.4	8.1	9.7	8.2	5.1	2.7

¹All values are on dry matter basis except dry matter.

The tannin content (condensed tannin) of PS was found to be 4.1% on dry matter basis, but values as high as 21% have been reported (Hill, 2002). Uteley and Hellwig (1985) reported an average value of 9.4% tannic acid equivalent. The variations in the values may be due to differences between analytical methods because estimation of tannin levels varies greatly between analytical methods. The value reported by Hill (2002) could be a combined value of both hydrolysable and condensed tannins (CT). The value in the current study represents CT

values, which are also referred to as proanthocyanidins which are generally found in forage legumes, trees, and shrubs (Barry and McNabb, 1999). As expected, the different amounts of PS in the diets resulted in different concentrations of EE percent (calculated) in the diets ranging from 1.6 in control diet to 5.7% in 30% PS diet when BGH and PS values were combined. No apparent palatability problems were noted relative to feeding PS containing diets. The handling problem was evident due to the fluffiness of the product; however, the concentrate portion of diets containing different levels of PS contained molasses to avoid the handling problem.

Fatty Acids

The fatty acids C14:0, C16:0 and C16:1 were similar ($p > 0.05$) among treatments in the longissimus muscle (LM) (Table 2). The C15:0 tended to increase linearly ($p = 0.09$) with increasing levels of PS in the diet but the C17:0 showed a quadratic response ($p < 0.05$). Similar to the results of this study, no clear dose-response relationship was observed for many minor fatty acids across all tissue samples by dietary treatments. However, steers on high fat containing diets produced lower ($p < 0.05$) percentages of C 14:0 and C 16:0 acids in the perinephric fat than did NOFAT-fed steers (Felton and Kerley, 2004). There is a paucity of data on fatty acid composition of different tissues for minor fatty acids in goats which makes it very difficult to compare these results to those of other results, although Celemens et al. (1974) concluded that ruminant adipose tissues are relatively insensitive to changes in type or amount of dietary fatty acids.

Table 2. Fatty Acid Profile (mass percentage; \pm SE) of Longissimus Muscle of Kiko X Spanish Crossbred intact Male Kids fed Diets with Varying Levels of Peanut Skins (PS).

Item	0	10	20	30	Linear	Quadratic
C14:0 (Myristic)	1.46	2.56	1.59	2.14	0.40	0.33
C15:0 (Pentadecylic)	0.31	0.42	0.41	0.49	0.09	0.51
C16:0 (Palmitic)	20.48	24.54	20.75	22.95	0.57	0.52
C16:1 (Palmitolic)	1.54	2.28	1.47	1.96	0.79	0.75
C17:0 (Margaric)	1.18	1.98	1.39	1.38	0.99	0.05
C18:0 (Stearic)	18.26	21.38	19.8	24.32	0.03	0.66
C18:1 (Oleic)	40.53	30.25	41.81	32.99	0.55	0.86
C18:2n-6 (Linoleic)	3.24	4.1	3.34	3.43	0.95	0.55
C18:3n-6 (Linolenic)	NA	NA	NA	NA	NA	NA
C20:4n6 (Arachidonic)	2.86	2.87	2.6	3.13	0.78	0.55
C20:5n3 (Eicosapentaenoic)	0.47	0.51	0.45	0.46	0.74	0.81
SFAs	41.60 \pm 3.19	53.66 \pm 3.19	46.35 \pm 3.49	50.39 \pm 3.19	0.20	0.23
UFAs	58.40 \pm 3.20	46.14 \pm 3.20	53.65 \pm 3.50	49.61 \pm 3.20	0.21	0.23
MUFAs	50.75 \pm 3.46	38.45 \pm 3.46	46.68 \pm 3.79	42.28 \pm 3.46	0.28	0.28
PUFAs	7.65 \pm 1.03	7.70 \pm 1.03	6.97 \pm 1.13	7.33 \pm 1.03	0.72	0.88

Note: SFAs = Saturated fatty acids; UFAs = Unsaturated fatty acids; MUFAs = Monounsaturated fatty acids; PUFAs = Polyunsaturated fatty acids; NA= Not available.

However, the C18:0 increased linearly ($p < 0.05$) with the increasing levels of PS. The increase may be due to the increased level of biohydrogenation (Banskalieva et al., 2000). The C18:0 is the predominant fatty acid in goat meat (Madruga et al., 2007), but the C:18 values in the current study were lower than the values reported for goat meat products (28.6 to 37.5%) by Madgura et al. (2007). On the contrary, Banskalieva et al. (2000) reported that the stearic acid in goat meat ranges from 6 to 17%. The stearic acid is commonly found in lamb and beef, but values for poultry and pork have higher amount of stearic acid compared to goats (Wood et al., 2003). The C18:1 and C18:2 levels were unaffected ($p > 0.05$) with dietary inclusion of PS (30 to 41%; 3.2 to 4.1, respectively). However, but their concentrations were within the normal range reported by others (e.g., Kott et al., 2010, in sheep fed safflower and high starch diets with a range of 27 to 35%, and Madgura et al., 2007, with a range of 2.4 to 5.0%) who collected goat viscera samples from healthy animals but feeding regimes were not discussed. However, Cummins et al. (2008) reported higher values, 41 to 46%, for oleic acid and 3.2 to 4.1% of LM of Boer X Spanish goat kids fed 0 to 200 ppm of copper for 30:70 forage and concentrate diets. Banskalieva et al. (2000) reported oleic acid range from 28 to 50% in goat muscle.

The C18:1, C16:0 and C18:0 constituted the major fatty acids in LM muscles but C18:1 was most abundant compared to other two fatty acids. The rib muscle fatty acid content (and presumably the carcass) of Ethiopian indigenous goats was primarily comprised of oleic acid (43.1-45.4%), followed by palmitic acid (23.1-24.3%) and stearic acid (16.5-20.6%). Similarly, Banskalieva et al. (2000), Mahgoub et al. (2002), Bas et al. (2005), and Pratiwi et al. (2006) reported similar proportions of fatty acid composition. The effect of diet is evident on fatty acid composition in goats (Sauvant et al., 1979; Manfredini et al., 1988). The C20:4n6 (Arachidonic acid) values ranged from 2.6 to 3.1% and are not different between treatments. The increased levels of C18:2 may be associated with PS, probably resulting, at least in part, from the high level of unsaturated fatty acids in PS.

Table 2 also shows that saturated fatty acids (SFAs) % in LM ranged from 42 to 54% and was within the range reported by Madgura et al. (2001), 47 to 49%, in goat meat from castrated Brazilian flocks. The unsaturated fatty acids (UFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) % in LM ranged from 46 to 58, 38 to 51, and 7 to 8%, respectively. The dietary inclusion of PS did not affect the values. The UFAs ranged from 45 to 59% in the LM. The unsaturated fatty acids, especially PUFAs, are hypocholesterolemic and are required for human growth development, reproduction, and health (Neuringer et al., 1988).

In the mesenteric adipose (MA) tissue (Table 3), C14:0, C16:0 and C18:0 were similar ($p > 0.05$) among treatments, but C15:0 tended to increase linearly ($p = 0.06$). The C15:0 comprises a large proportion of rumen microbial fatty acids (Vlaeminck et al., 2004). The higher level of fat content due to higher level of PS in the diet may have changed the microbial profile in the rumen, thereby, causing differences in C15:0. The C16:0 decreased linearly ($p < 0.05$) with increasing dietary level of PS, but C16:1, C17:0 and C18:1 showed quadratic responses ($p < 0.05$) with dietary inclusion of PS. The C18:0 increased linearly ($p < 0.05$) as the level of PS increased in the diet. Although C18:0 is a saturated fatty acid, it is considered a neutral fatty acid (Duckett and Pavan, 2007). The oleic acid (C18:1) showed a quadratic response ($p < 0.05$), but linoleic and linolenic acids decreased linearly ($p < 0.05$). Regardless of the location of the adipose tissues, the major fatty acids of fat depots are C18:1, C18:0, and C16:0 followed by

C14:0, C16:1, C17:0, and C18:2 (Banskalieva et al., 2000). The visceral fat (i.e., mesenteric) is the earliest developing fat, followed by intramuscular, subcutaneous, and intramuscular fat (Casey et al., 2003).

Table 3. Fatty Acid Profile (mass percentage; \pm SE) of Mesenteric Adipose Tissue of Kiko X Spanish Crossbred intact Male Kids fed Diets with Varying Levels of Peanut Skins (PS).

Item	0	10	20	30	Linear	Quadratic
C14:0 (Myristic)	2.73	2.68	2.7	2.49	0.34	0.63
C15:0 (Pentadecylic)	0.59	0.56	0.65	0.65	0.06	0.62
C16:0 (Palmitic)	24.34	23.57	24.06	21.92	0.02	0.28
C16:1 (Palmitolic)	1.03	0.83	0.75	0.75	0.001	0.01
C17:0 (Margaric)	2.68	1.09	0.84	1.05	0.001	0.001
C18:0 (Stearic)	35.2	38.36	37.95	39.16	0.03	0.41
C18:1 (Oleic)	28.27	26.39	26.6	27.58	0.55	0.05
C18:2n-6 (Linoleic)	1.55	1.27	1.12	0.94	0.001	0.48
C18:3n-6 (Linolenic)	0.16	0.14	0.12	0.12	0.001	0.17
C20:4n6 (Arachidonic)	0.13	0.11	0.1	0.11	0.13	0.15
C20:5n3 (Eicosapentaenoic)	0.11	0.12	0.1	0.1	0.28	0.62
SFAs	65.76 \pm 1.95	65.92 \pm 1.95	66.92 \pm 2.14	62.76 \pm 1.95	0.37	0.29
UFAs	34.24 \pm 1.95	34.08 \pm 1.95	33.08 \pm 2.14	37.24 \pm 1.95	0.37	0.29
MUFAs	32.05 \pm 1.84	31.99 \pm 1.84	31.10 \pm 2.02	34.95 \pm 1.84	0.36	0.31
PUFAs	2.19 \pm 0.18	2.09 \pm 0.18	1.98 \pm 0.20	2.29 \pm 0.18	0.82	0.28

Note: SFAs = Saturated fatty acids; UFAs = Unsaturated fatty acids; MUFAs = Monounsaturated fatty acids; PUFAs = Polyunsaturated fatty acids.

SFAs and UFAs did not differ ($p > 0.05$) among treatments although fat contents of diets varied. The SFA values were higher than in LM muscles. SFAs and UFAs sum up 100%. Total MUFAs and PUFAs were similar between treatments. The amounts of saturated fatty acids were higher in the mesenteric muscle compared to the LM muscle. Ruminant fats are more saturated as compared with those of nonruminants. One of the differences between ruminants and nonruminants is that ruminant fats are more difficult to alter due to the considerable capacity of the rumen to alter and hydrogenate unsaturated fatty acids (Dawson and Kemp, 1970). UFAs are readily hydrogenated by rumen microbes to more saturated end products. The evolutionary role of rumen microbes as regards to biohydrogenation is to protect rumen microbes from toxic effects of UFAs, although biohydrogenation contributes little, as a hydrogen sink; only 1 to 2% of metabolic hydrogen (Czerkawski and Clapperton, 1984).

In the subcutaneous adipose (SA) tissue (Table 4), the C14:0 and C15:0 were similar ($p > 0.05$) among dietary treatment groups. The C16:0, C16:1, C18:0, and C18:1 showed a quadratic response ($p < 0.05$) with increasing levels of PS in the diet. The C16:0 is a marker of lipogenesis (Murray et al., 1996) and the primary product of fatty acid metabolism in growing sheep (Kott et al., 2010). Similarly C20:4n6 (arachidonic acid) responded in the same way. The linoleic and

linolenic acids were unaffected by dietary treatments. SA tended to increase in a quadratic manner ($p = 0.007$). Similarly, MUFA increased quadratically ($p = 0.02$), but PUFA was similar ($p > 0.05$). According Banskalieva et al. (2000), lipids deposited in goats consist mainly of SFA (30-71%) and MUFA (20-75%); PUFA (i.e., sum of C18:2 and C18:3) are less than 6% in some fat depots. Subcutaneous fat depots are less saturated in goats; are relatively higher in MUFA, and contain less C18:2, C18:3 compared to sheep (Banskalieva et al., 2000). MUFAs are considered antithrombogenic lowering low density lipids (LDL) cholesterol, and raising high density lipids (HDL) (Mensink and Katan, 1989; Ulbricht and Southgate, 1991). Results of the current study are in agreement with Banskalieva et al. (2000). The percent MUFA decreased quadratically ($p < 0.02$) but PUFA percents were similar. The oleic acid was the major fatty acid in the SA tissues, followed by palmitic acid and stearic acid. Mahgoub et al. (2002) also reported that fatty acids composition of goats is primarily comprised of oleic acid (43.1-45.4%), followed by palmitic acid (23.1-24.3%), and stearic acid (16.5-20.6%) for different goat muscles. The level of SFA is lower in LM compared to UFA across all treatments but it was opposite in the MA and SA tissues. This makes sense because the latter two tissues are storage tissues.

Table 4. Fatty Acid Profile (mass percentage; \pm SE) of Subcutaneous Carcass of Kiko X Spanish Crossbred intact Male Kids fed Diets with Varying Levels of Peanut Skins (PS).

Item	% PS				P-Value	
	0	10	20	30	Linear	Quadratic
C14:0 (Myristic)	3.87	3.34	3.15	3.55	0.51	0.25
C15:0 (Pentadecylic)	1.5	1.13	1.03	1.7	0.65	0.59
C16:0 (Palmitic)	24.65	25.9	25.28	23.39	0.15	0.04
C16:1 (Palmitolic)	4.47	2.39	2.27	2.95	0.13	0.05
C17:0 (Margaric)	2.42	2.59	2.39	2.08	0.29	0.36
C18:0 (Stearic)	13.38	20.83	22.08	16.58	0.43	0.05
C18:1 (Oleic)	41.58	38.02	37.98	41.69	0.96	0.05
C18:2n-6 (Linoleic)	1.14	1.2	1.04	1.14	0.75	0.86
C18:3n-6 (Linolenic)	0.22	0.21	0.19	0.23	0.91	0.23
C20:4n6 (Arachidonic)	0.1	0.1	0.05	0.13	0.66	0.06
C20:5n3 (Eicosapentaenoic)	NA	NA	NA	NA	NA	NA
SFAs	40.76 \pm 3.29	51.68 \pm 3.32	58.33 \pm 3.65	48.63 \pm 3.33	0.06	0.07
UFAs	59.24 \pm 3.33	48.32 \pm 3.33	41.67 \pm 3.65	51.37 \pm 3.33	0.06	0.007
MUFAs	55.12 \pm 3.68	44.01 \pm 3.68	37.88 \pm 4.03	45.80 \pm 3.68	0.05	0.02
PUFAs	4.12 \pm 3.04	4.31 \pm 3.04	3.79 \pm 3.33	5.57 \pm 3.40	0.78	0.83

Note: SFAs = Saturated fatty acids; UFAs = Unsaturated fatty acids; MUFAs = Monounsaturated fatty acids; PUFAs = Polyunsaturated fatty acids; NA= Not available.

In general, the results clearly indicate that oleic acid (C18:1) is the main fatty acid in all tissues of goat analyzed in the present study except in the MA tissue. This agrees with the results presented by several researchers (Sauvant et al., 1979; Park and Washington, 1993; Matsuoka et al., 1997). Rhee et al. (2000) showed that the oleic acid constituted more than the two-thirds of UFAs in the intramuscular fat from Boer X Spanish goats. It was also evident that internal fat depots in goats are more saturated than subcutaneous fat depots and LM fat depots. Similar results have been reported in sheep, cattle, and pigs (Belibasakis et al., 1990). Their results with lamb showed that internal fat depots are more saturated than subcutaneous fat (Kemp et al., 1981; Banskalieva, 1996). Fat composition is influenced by many factors such as age, sex, nutrition, body weight, growth rate, physiological condition, and physical activity (Owen and Norman, 1978; Kirton, 1988). The supplementation of soybeans, sunflower seeds and canola oil has been shown to increase intramuscular UFAs and decrease in SFAs in lamb rams (Lough et al., 1992).

Conclusion

The results demonstrate that the fatty acid composition of goat carcass can be altered with dietary addition of PS. Based on the fatty acid profile of different tissue samples, PS can be added up to 30% of the diet dry matter for growing meat goats without any adverse impact on the health and growth of goats as well as the fatty acid quality for consumption for health conscious consumers. Based on these results, PS can be recommended for supplemental feeding for meat goats. Also, PS are a cheap source of feedstuff available in the Southeastern U.S., and producers can use them to lower their cost of production.

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