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Review Article

Goat meat: Some factors affecting fat deposition and fatty acid composition

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Abstract

Goat meat has recently become an important aspect in the meat markets due to its containing of low fat, and cholesterol contents that may benefit to human health as compared to mutton, pork, and beef. Some of the factors such as rearing system and nutritional supply, breed, gender, age, and weight at slaughter are influencing on fat deposition and fatty acid composition in goat meat. Nevertheless, each factor is not independent but has association with others. From literature reviews, rearing and nutritional systems seem to be the most important factors that have influence on fat deposition and fatty acid composition in goat meat than others.

Keywords: goat meat, fat depot, fatty acid composition

1. Introduction

Goat meat is commonly consumed in many parts of the world for particular in Asia and Africa, although its consumption is less as compared to pork, poultry, and beef (Food and Agriculture Organization of the United Nations [FAO], 2015). Nevertheless, since consumer preferences of meat concern more on healthy meat, goat meat becomes an alternative red meat to fulfill this need. This is due to the lower fat and cholesterol contents in comparison to mutton, pork, beef, and broiler meat (Banskalieva *et al.*, 2000; Casey, 1992). As a low fat meat, some major factors, such as production and nutritional systems, breed, gender, age, and weight at slaughter that have an influence on fat deposition and fatty acid composition as discussed in this review. Information gained from this paper should be beneficial for manipulating these basic factors that relate to the further development of goat meat production.

2. Rearing and Nutritional Systems

Rearing systems can be expressed in terms of production system or the management system and nutritional system. In goat, effects of different rearing systems in growth performance and carcass parameters including fat deposition related to meat quality were discussed by many works such as Awah and Adeleye (1997), Banskalieva *et al.* (2000), Goetsch *et al.* (2011), Webb *et al.* (2005). Under intensive care, when goat received excessive nutrient supply for a period of time, better live weight and carcass weight could be noticed while more viscera fat and inter-muscular fat could be found than those reared under semi- or extensive systems of either young or mature goats (Daskiran *et al.*, 2006; Khaokhaikaew *et al.*, 2010; Legesse *et al.*, 2006; Rajkumar *et al.*, 2010).

When discussing about the plane of nutrition, the study found that high plane of nutrition increased not only for growth performance but also enhanced for the onset of rapid fattening phase of both sexes as described by Awah and Adeleye (1997). In addition, more fat contents at kidney, heart, omental, and pelvis parts including subcutaneous were commonly found in goats when received high amount of concentrate supplementation than those fed only roughage (Legesse *et al.*, 2006; Marques *et al.*, 2014). Under good quality roughage and supplement concentrate diet with 15% crude protein at different energy levels (low: 10.44 MJ ME/kg DM, medium: 11.60 MJ ME/kg DM, and high energy: 12.90 MJ ME/kg DM) did not show any significant difference on meat

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quality including total fat and intermuscular percentages ($P< 0.05$) of castrated male black kids (Abdullah & Musallam, 2007). Work of Pengbunsom *et al*. (2006) indicated that supplement concentrate with 14% CP and 11.34 MJ ME/kg DM to either Thai indigenous or Thai indigenous x Anglo-Nubian crossbred goats had sufficiency to improve their productivity and meat yield with lowered production. Nevertheless, by discussing based on the empty live weight, Pralomkarn *et al.* (1995) did not find any significant effect on a high plane of nutrition (maintenance (M), 1.2M and 1.9M) on the body composition, including omental fat and carcass dissectible fat of Thai indigenous and Thai indigenous x Anglo-Nubian weaner goats) although goats became fatter when feed intake increased. From the literature review it could be concluded that under intensively management with higher amount of concentrate supplementation, goats have a well-conformed and heavy carcass with the high amount of fat deposition in the abdominal cavity and around the carcass than those reared extensively.

Higher chemical fat percentage in meat from goats reared under feedlot system than meat from those reared under the pasture (Madruga *et al*., 2006; Rodrigues *et al.,* 2011). This was in agreement with Rajkumar *et al*. (2010) who noticed a higher chemical fat in the meat of the Sirohi goats reared under an intensive production system than those reared under semi-intensive system (9.27% vs. 4.97%). However, the percentage of proximate fat in meat might relate to the age of goat as mentioned by Toplu *et al*. (2013).

Fatty acid composition is an important point when discussing about meat quality. The amount values of SFA (saturated fatty acids) in goat meat and other ruminant meats were generally higher than those of the UFA (unsaturated fatty acids) (Banskalieva *et al.*, 2000; Park & Washington, 1993). This is due to the biohydrogenation by the rumen microbes (Banskalieva *et al.*, 2000). However, considering the type of UFA, the study indicated that the amount of MUFA (mono-unsaturated fatty acid) in meat could rise up when fed more concentrate diet. In contrast with MUFA, the amount of PUFA (poly-unsaturated fatty acid), especially n-3 PUFA, will increase in goat meat fed grass (Rhee *et al*., 2000). The ratio of PUFA per SFA in goat meat was in the ranges of 0.16 to 0.49 (Banskalieva *et al.*, 2000). From the review, nutritional system could be confirmed for having significant effects on fatty acid composition (Banskalieva *et al.*, 2000; Özcan *et al*., 2015; Rhee *et al.*, 2000; Sukniam *et al.*, 2009). The fatty acid composition in meat from goats reared under extensive and feedlot systems were presented in Table 1.

3. Breed

The breed is a source of variation is clearly known in carcass morphology related to fat quantity or meat quality as mentioned by Guerrero *et al*. (2013). In detailed reviews by Assan (2015), Banskalieva *et al.* (2000), Goetsch *et al.* (2011), Horcada *et al*. (2012), and McGregor (1984) on this topic pointed that breed exerts an influencing on fat deposition and the profile of fatty acid of goat meat. Work of Dhanda *et al.* (1999a) showed that different breeds of goat carcass were about 10% to 13% difference of total fat content with no significant difference in carcass weight. Dairy goat breeds tended to store more fat as visceral rather than carcass adipose tissue (Hogg *et al*., 1989; Latif *et al.*, 1987). Moreover, the dairy kid tended to deposit more internal fat than the meat type (Dhanda *et al.*, 1999a). This previous results were confirmed by the work of Horcada *et al.* (2012) who found that Spanish dairy goat breeds deposited more carcass fat than those of the Spanish meat goats. However, the increasing rate of fat content was not differed only among the breed types but was associated with the age (Mtenga, 1979), rearing system, and nutritional quality and quantity (Sañudo *et al*., 2000).

Goat breed with small body size (Dhofari) had a higher total body fat and total non-carcass fat than the large body size breed (Batina) (Mahgoub & Lu, 1998). This was similar to the work of Pengbunsom *et al*. (2006) who noticed that the small body size of Thai indigenous goat had a lesser carcass weight with a greater fat percentage than a medium body size goat of Thai indigenous x Anglo-Nubian. However, the high variation among breeds of goat which differs from the average maturing body size might due to the influence of nutritional management and physical status (Horcada *et al.*, 2012; Sañudo *et al*., 2000). Nevertheless, the increasing rate of fat deposition may differ among the breed types (Dhanda *et al*., 2003a, 2003b; Horcada *et al*., 2012) and the age, although all breed types generally store fat at the visceral part rather than other parts such as subcutaneous fat, inter-, and intramuscular fat (Banskalieva *et al.*, 2000; Goetsch *et al.*, 2011; Mahgoub & Lu, 1998).

Breed did not only affect the partitioning of fat but could be likewise affected the quantity of crude fat and the fatty acid profiles in meat and adipose tissues. Reports from the work of Dhanda *et al*. (2003b) emphasized that breed difference had a significant effect on the fatty acid profiles of goat fat tissue. This study was in accordance with the works of Park and Washington (1993). Breed related to the fatty acid

Table 1. Effect of rearing systems on percentage fatty acid composition of *semimembranosus*, *semitendinosus* and *biceps* muscles obtained from Mestço goats [a/].

Fatty acids (%)	Rearing systems	
	extensive [b/]	confinement [c/]
14:0	2.41[a]	1.83[b]
14:1	0.44[a]	0.48[a]
16:0	19.64[a]	20.12[a]
16:1	1.87[b]	2.60[a]
17:0	1.64[b]	1.63[a]
17:1	1.80[a]	1.45[a]
18:0	20.71[a]	17.03[b]
18:1	36.23[b]	43.56[a]
18:2	9.06[a]	6.84[b]
18:3	3.62[a]	2.53[b]
20:3	0.25[a]	0.22[a]
SFA	45.52[a]	41.42[b]
MUFA	41.52[b]	49.04[a]
PUFA	12.94[a]	9.59[b]
PUFA/SFA	0.29[a]	0.23[a]
UFA/SFA	1.22[b]	1.42[a]
MUFA/SFA	0.93[b]	1.19[a]

[a/] reared intact male goat at 18.3±0.5 kg of initial live weight until 30 kg of live weight; [b/] received typical native brushwood of Northeast region of Brazil called "Caatinga"; [c/] received ensilage containing maize and a mixture of soy, wheat, molasses and minerals, in the ratio of 40:60 at 4% of live weight.; [d/] Means within the same row followed by a common letter are not different ($P>0.05$). Adapted from Madruga *et al.* (2006).

profile was also reported by Madruga *et al*. (2009) who found a significant difference between breed (pure Boer, Boer x SPRD (Without Racial Standard Defined), and Anglo-Nubian x SPRD) and fatty acid profiles either SFA or UFA. This study was similar to the works of Werdi Pratiwi *et al*. (2006). In dairy kids, Özcan *et al*. (2015) illustrated a significant breed affecting fatty acid profile in the percentages of myristic acid (C14:0), palmitic acid (C16:0), oleic acid (C18:1 n-9), linolenic acid (C18:3 n-3), arachidonic acid (C20:4 n-6), and docosahexaenoic acid (C22:6 n-3), although no significant effects were indicated on the ratios of polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA) and n-6/n-3. From the early part of this review, the amount of UFA might increase when the amount of concentrate feeding increased. However, breed difference should not be an individual factor that had influence on the profile of fatty acid, but breed in associate with production and nutritional systems and age of goats would have important factors in the profile and amount of fatty acid (Banskalieva *et al.*, 2000; Dhanda *et al*., 2003b; Goetsch *et al.*, 2011; Özcan *et al*., 2015; Rhee *et al.*, 2000).

4. Gender

Gender is one of an important factors influencing on the growth of body tissues and carcass composition of animals described by Berg and Butterfield (1968) when fat deposition in goat was influenced more by breed and nutriational status than the gender (Webb *et al*., 2005). The proportions and locations of fat deposition in the body did not only depend on gender, but also related to the nutritional supply (Abdullah & Musallam, 2007), age (Toplu *et al*., 2013) and mature size (Mahgoub & Lodge, 1996; McGregor, 1984). Based on the works of Mahgoub and Lodge (1996), the proportion of total body fat based on the empty live weight was in the range of 16% to 23.5% at 28 kg of live weight in bucks, wethers, and does goats. However, the total body fat, total carcass fat, and total non-carcass fat were increased when the age increased (Mahgoub *et al.*, 2004). For this study, does and wethers had a faster rate of deposition of carcass and non-carcass fat relative to empty live weight than the bucks. Effect of gender on carcass percentage and non-carcass fat deposits is shown in Table 2.

Under high plane of nutrition, more fat deposited in the carcass and non-carcass tissues of female than that of the entire and castrated male goats (Mahgoub & Lodge, 1996). Similar results were determined in castrated male black goats by Abdullah and Musallam (2007), and also in castrated male Thai x Anglo-Nubian male goats reported by Anneke (2017). Nevertheless, the results of the previous studies did not in accordance with the report of Tahir *et al.* (1994) who did not find any significant differences in meat, fat, and bone from the major cuts of the entire and castrated male goats.

For the relationship between castration and fattening period, Zamiri *et al*. (2012) examined the effect of castration at three months of age and fattening periods (2, 3, 4, 5 or 6 months of fattening) on the feedlot performance and carcass characteristics of Fars native male kids. This study did not obtain any significant difference between the castrated and intact kids at 2, 3, and 4 months of fattening. However, at 5 and 6 months of fattening, the carcass lean and fat percentages had significant differences between the intact (68.8% and 8.5%, respectively) and castrated male goats (65.4% and 12.5%, respectively). With castration, a fattening period of three months is recommended for the male goat.

In terms of chemical fat, meat from the female had the highest amount of crude fat followed by castrated male and entire male goat (Johnson *et al*., 1995). This was in accordance with the work of Rodrigues *et al*. (2011) who found higher crude fat percentage in meat from the female goats than the male goats. Similar work was obtained likewise by Anneke (2017) that under the same breed type, age, and feeding management, meat from castrated male goat deposited higher crude fat percentage than the entire males. This was related to the lack of male sex hormone that could lead to store more fat.

In terms of the effect of gender on fatty acid profiles of meat, results from many research works showed that gender could influence on the amount and type of fatty acid composition of goat tissues, although the data were inconsistent and might depend on many factors such as types of feed, age, and weight (Banskalieva *et al.*, 2000; Goetsh *et al.*, 2011). Report from Özcan *et al.* (2015) illustrated that male kids had a higher percentage of C18:0, C18:3 n-3, and C22:2 n-6, while the females had greater percentages of C18:1 and C20:1. This was similar to the report of Matsuoka *et al.* (1997) who

Table 2. The effect of gender on fat deposition of Omani Jebel Akhdar goats at 11, 18, and 28 kg of slaughter weight.

Fat depot [1/]	Buck			Wether			Doe		
	11 kg	18 kg	28 kg	11 kg	18 kg	28 kg	11 kg	18 kg	28 kg
Omental	0.77	1.48	2.68	1.13	2.15	2.39	1.57	2.46	4.47
Mesental	1.31	1.36	1.80	1.28	1.56	2.21	1.43	1.56	2.51
Scrotal /udder	0.41	0.61	0.79	0.39	0.75	0.78	0.56	0.80	1.01
Kidney	0.83	1.00	1.50	0.99	1.29	1.56	1.13	1.36	2.83
Channel	0.06	0.10	0.14	0.07	0.10	0.10	0.11	0.20	0.23
Pelvic	0.22	0.28	0.30	0.24	0.26	0.30	0.28	0.25	0.36
Total non-carcass fat	3.61	4.82	7.20	4.10	6.11	7.32	5.82	6.63	11.41
Subcutaneous	1.32	2.49	3.22	1.81	3.32	4.29	1.48	3.79	5.53
Intermuscular	2.71	3.54	5.21	4.14	4.70	5.53	3.07	4.61	6.57
Total carcass	4.03	6.03	8.43	5.98	8.01	9.82	4.55	8.40	12.09
Total body fat	7.64	10.85	15.63	10.62	14.12	17.27	11.11	15.03	23.50

[1/] % of empty live weight. Adapted from Mahgoub *et al.* (2004).

studied on Japanese Saanen goat breeds. Nevertheless, the different amount and type of fatty acid composition of goat tissues were mainly related to the type of feed and especially roughage that goat received (Goetsh *et al.*, 2011).

5. Age and Slaughter Weight

The development of fat in goat will occur very late and only reaches appreciable levels when goat gets close to the mature size (Owen *et al*., 1978). This mature size in goat varies from 20 kg for indigenous breeds to over 100 kg for an improved breed such as a Boer goat (McGregor, 1984). The early mature goat might depot fat faster than the late mature goats, and most of fat that occurs in goat carcass is majority found in the visceral part rather than it will be found in the other parts (Mahgoub & Lodge, 1996). However, age may not directly effect on the degree of fat deposition and the profile of fatty acid but will be in associate with the plane of nutrition (Goetsch *et al.*, 2011; Toplu *et al.*, 2013). Thus, under good nutritional supply when the slaughter age of goat increases, not only amount of visceral fat will increase, but the amount chemical fat in meat was possible to be increased (Beserra *et al*., 2004; Zamiri *et al*., 2012). A similar result was reported by Aktaş *et al*. (2015) with the emphasis that fat content increased with slaughter age and gained weight although this also depended on the feed characteristics and plane of nutrition that goats received (Goetsch *et al.*, 2011). This was in corroborating with the study of Pralomkarn *et al*. (1995) who found an increasing of omental fat when the ages of Thai indigenous and Thai indigenous x Anglo-Nubian goats increased from 6.9 to 11.6 months.

Conclusions

There are many factors that can affect fat deposition and fatty acid composition in goat meat such as rearing system and nutritional supply, breed, gender, age, and weight at slaughter. From literature reviews, however, rearing or production systems and nutritional conditions are the most important factors that influence on fat deposition and fatty acid profile in goat meat associated with breed, gender, age, and slaughter weight. Under sufficient nutritional supply and good rearing system, not only better live weight and carcass weight can be indicated, but also more fat deposition, particularly on the visceral part can be found. Nevertheless, type of diet, either roughage or concentrate, can affect the amount of fat deposition and the profile of fatty acid, especially the amount of n-3 PUFA that may be increased in grass-fed goats in goat meat. Breed differences can influence on the fat deposition and fatty acid profile in meat when goats received a sufficient nutritional supply for a period of time. Female goats have more fat deposition rapidly in carcass and non-carcass tissues than that of castrated and non-castrated male goats. In fact, the early maturing goat may deposit fat faster than the late mature goat, but this will have an associated effect with plane nutrition.

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