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Investigations Relating to Fat-tail Sheep

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INTRODUCTION

The Fat-tail type of sheep is probably the most important in the world in terms of its overall contribution to mankind. It has been estimated (1) that possibly as much as 1/3 of the world's sheep population are of this general type. This is exceeded only by the Fine-wool types (Merino or breeds derived from Merino). However, the latter types are, in many countries, exploited with the primary emphasis on wool production. By contrast, many of the Fat-tail types are used for the production of milk, meat and wool. It is not unusual that milk is the most important product obtained, and fat-tail sheep are commonly produced in areas or developing countries where output from the sheep industry makes a more important contribution to meeting man's need for food and fiber.

There are many breeds or types of fat-tail sheep. Perhaps the two most prevalent and best known of this group are those known as the Karakul and Awassi. The Karakul is the breed used for the production of Persian lamb pelts, (in actual practice, however, a large portion of the lambs produced are not sacrificed for pelt production), but instead are later utilized for meat production. The Awassi breed is widespread in the Middle East and adjacent regions and is noted as a superior breed for milk production (2). Essentially all Fat-tail types have a number of characteristics in common. In addition to the deposition of the fat in the tail, they are essentially all adapted to arid regions with wide ranges in environmental temperatures, they produce carpet wool, they generally have low twinning rates (3), they have well developed flocking instincts, and they can travel long distances. In many areas, a distinct preference is shown for the meat of fat-tail sheep over that of other types. In addition, the areas where fat-tail sheep are produced are noted for a high level of lamb or mutton consumption whereas lamb or mutton consumption is often low or declining in areas where fine-wool types are produced. Although the explanation for this trend is not apparent, it has important implications for the sheep industries in many parts of the world. Fat-tail types are those normally produced and consumed in the Near East and Persian Gulf areas which are net importers of sheep meat. Some of the more important exporting countries, such as Turkey, also produce fat-tail sheep. Thus, any unique aspects of these animals have implications for world trade in sheep meat.

Also, there appears to be a need to consider changes in the industry where fat-tail sheep are produced. As early as 1961, Epstein (2) indicated a strong consumer aversion to fat meat in Israel resulting in fat trim of the fat-tail sheep carcasses being used for the manufacture of soap or animal feed. Mehran and Filsoof (4) stated "due to the introduction of the shortening industry in Iran, the demand for sheep tail-fat for nutritional purposes has been decreasing...". This can be shown to be true in many countries where these sheep are produced. Nevertheless, there appears to be a reluctance for workers in these regions to suggest considerations of a need to change.

Although extensive research has been conducted with sheep, much of this has been done with the Merino type or those types found in temperate climates. Less research work has been done with the Fat-tail types. It seems fitting that an activity with international implications such as the Small Ruminant Collaborative Research Support Program (SR-CRSP) should have an interest in these animals.

The only Fat-tail type of sheep known to be present in the U.S. is the Karakul. A small number of Karakuls were brought to Archer County, Texas in 1908 from Bokhara or Turkistan which is presently a part of the Soviet Union (5). Other importations, consisting of small numbers have been made since that time. The name Karakul apparently derives from a town of the same name in Turkistan. A pelt industry based on the Karakul existed for a time in the U.S., but seems to have died out prior to 1940. Experimental flocks were maintained for a period of time by the Texas Agricultural Experiment Station (6) and by the U.S. Department of Agriculture (7). The number of Karakuls in this country has reached a very low point at the present time. A small research flock was established by the Texas Agricultural Experiment Station to assist in maintenance of this genotype in this country and to collect pertinent research information which might contribute to the overall goals of the SR-CRSP. Some very important questions relating to this general type of sheep have to do with their adaptation to adverse environments, the eating qualities of their meat, the relationship of the tail to adaptation and to reproductive efficiency. There is also a need to explain the origin of the fat-tail trait.

Material and Methods

In 1979 a small number of Karakul sheep were obtained and brought to the experimental flock maintained at San Angelo, Texas (see figure 1). The animals were obtained from range flocks in New Mexico. Prior to that time, some limited crossbreeding studies had been conducted utilizing two Karakul rams obtained at an auction market in Texas. Since 1979, a series of studies has been conducted and the results will be reviewed under various subject matter headings in this report. In this series of studies, the Karakul has been used as an example of the larger fat-tail group, even though it may be debatable to what extent data from this breed can be extrapolated to the larger population.

Results and Discussion

Comparative Ewe Performance

During the period of years covered by this report, ewe flocks of grade Finnish Landrace, Rambouillet and Karakul were maintained on the Station. Breed comparisons were not a part of the experimental plan and the ewes were not always managed under the same conditions, but they were generally treated in a similar manner. Thus, specific data on breed comparisons will not be reported. However, some comments seem to be warranted. The Karakuls are more hardy and represent an "easy care" sheep. Ewe body weights and especially condition tend to be higher for the Karakuls under adverse range conditions. Karakul ewes also sustain lower annual death losses. Somewhat surprisingly, the Karakuls used in this study were wilder and more difficult to handle. The Karakuls have the lowest lambing rates of the three types (i.e., 1.17 lambs born per ewe lambing compared to 1.43 for Rambouillet). There were no significant differences in the percent ewes lambing, but in total number of lambs dropped the Karakul was the lowest. Percent lamb survival was highest for the Karakuls, even when corrected for type of birth.

However, the survival advantage was not enough to overcome their lower reproductive parameters. Under prevailing range conditions, average weaning weights were higher for the lambs produced by Karakul ewes but, under other experimental conditions, weight gains of lambs on feed tended to favor Rambouillets. In respect to fleece weights, the Karakuls were intermediate between the other two breeds (6.3 lb. compared to 10.0 for Rambouillet), and in traditional market channels in this country, the market value of the Karakul fleece was much lower. This was explained by its coarser (and more variable) diameter (29.2 microns compared to 20-22 micron for Rambouillet) and a higher colored fiber content (8). There is a potential market for use of the carpet-type wool in home craft industries if it can be exploited. Thus, the fat-tail (Karakul) sheep would not have an advantage over the finewool (Rambouillet) in this country except possibly under very harsh conditions where survival of the ewes and lambs are in question. There is no reason to predict or to recommend a return to use of the Karakul unless a lamb pelt industry is revived and that does not appear likely. Therefore, domestic interest in the Karakul will likely rest on maintaining this genotype in the U.S. for purposes of studying some of the unique aspects of these sheep, investigating them because of their importance on an international scale or learning things about them which may be of local interest.

Relationship of the Fat-Tail to Reproduction

It seems obvious that the fat tail of the Karakul ewe provides some impediment to mating (figure 2). The degree to which this is true would, to some extent, be a function of the condition of the ewe and thus of the amount of fat in the tail. It is generally recognized that producers of fat-tail sheep use a higher ram to ewe ratio than is used with other types of sheep. The rams must be also older or more experienced before they can be relied on for breeding. In addition, a significant portion of the fat-tail sheep in several countries are produced on state farms or government farms in which artificial insemination is practiced, no doubt in part because of the physical difficulties associated with mating. Also, many managers of institutional flocks and private producers assist in the mating process by holding the tail of the ewe to the side during mating. There is a also a general belief, partially supported by observations, that rams of the fat-tail breeds are more likely to be successful in mating these types of ewes than are rams of other types (9).

Test of Mating Success;

Two tests were conducted in which the ability of rams to serve fat-tail ewes were evaluated. In the first test, 12 rams of the Finnish Landrace, Karakul, Rambouillet and Booroola x Rambouillet breeds were exposed for 10 minutes each to a restrained non-docked fat-tail ewe. The ewe or ewes utilized were not in estrus at the time. The 12 rams made a total of 107 mounts or attempts to mate the ewes. None of these were successful. For the most part, these were young rams, but one experienced Karakul ram was used. These data indicate the extent to which the fat-tail is an impediment to mating. This test also failed to show a breed difference in the rams ability to mate the ewe since no services occurred.

Figure 1. One of the Karakul rams used in these studies. They may be horned or polled and the color may range from black to white.

Figure 2. The fat tail is a definite impediment to mating. This mature ram of one of the fat-tail breeds of the Middle East was observed for several minutes, and was unable to serve the ewe.

In a second test, 10 rams of the same four breeds were exposed 32 different times for a 10 minute period to restrained Karakul ewes. One half of these exposures were to a docked ewe and half to an undocked ewe. Several of the rams used in this test were young, inexperienced rams, some of which did not attempt to serve either of the ewes under test conditions. However, when exposed to the docked ewes, 14 attempts were made to serve the docked ewe of which 11 or 78.5% were successful. The rams made a total of 123 mounts or attempts to serve the undocked ewe without success. Again, there was no documentation of a difference due to breed of the ram as individual rams of each of the breeds were successful in mating the docked ewe and none of the rams, regardless of the breed, was successful in mating the undocked ewe.

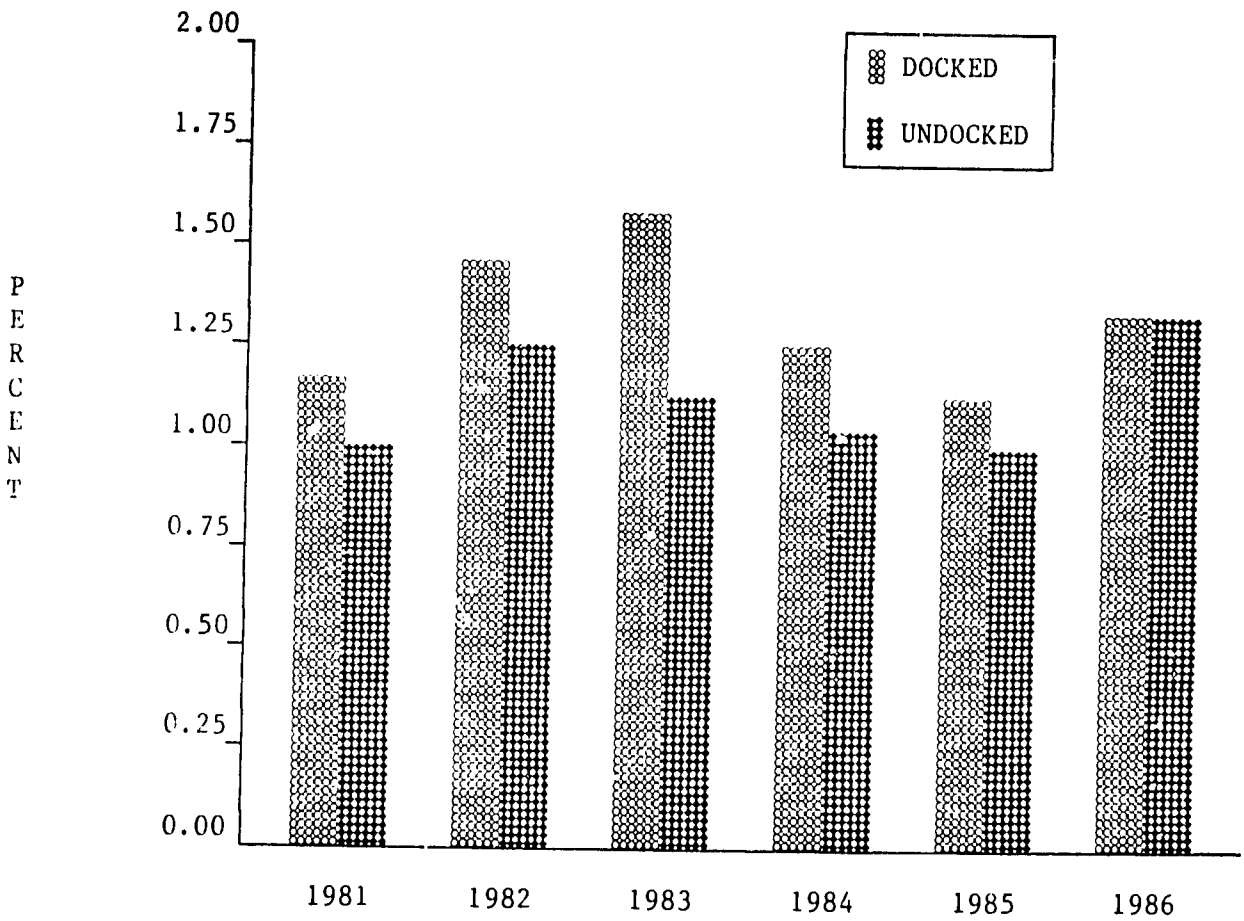
These tests were conducted prior to the start of the breeding season with the result that none of the rams had been exposed to a ewe for approximately one year, and some had not been used previously. These data certainly document the interference of the fat tail to mating success. However, the negative results obtained in these tests cannot be truly indicative of what occurs under field conditions since lamb crops are obtained under production conditions. Therefore, a further study was conducted in which docked and undocked ewes were compared under field conditions.

Comparisons of docked vs undocked ewes;

Each year, a random sample of approximately one half of the lambs of each sex were closely docked and the remainder were left undocked. The females were added to the flock and were later evaluated in respect to reproductive performance over a six-year period. The ewes were exposed as a group to two Karakul rams either concurrently or consecutively. The rams were put with the ewes in August of each year. The results are shown in Table 1. These data generally show the reproductive performance of docked ewes to be superior to that of undocked ewes. The most marked difference was in the percent ewes lambing and in the lambing date. The lambing date represents the average number of days from the time the rams were put out until lambing. These data suggest that the docked ewes were mated first. The difference is approximately 1/2 the length of the estrus cycle. The percent ewes lambing was improved by docking; however, much of this was accounted for in one year in which the lambing rate of the undocked ewes was much lower. Both of these observations suggest again that the ability to mate the undocked ewes is a learned experience which may be highly variable between rams and years. There was also a significant difference between the docked and undocked ewes in lambing rate (lambs born per ewe lambing). Differences between docked and undocked ewes are more marked in the actual data --by years-- than is shown by the least square mean value in table 1.

Comparative values for the docked and undocked ewes for the years 1981 through 1986 are shown in Figure 3. An explanation for the observed difference is unclear, but some possibilities can be suggested. One hypothesis is that the fleshier undocked ewes with more fat in their tails may be those which are less likely to be mated, and, it is known that fatter ewes tend to have higher lambing rates. Condition scores were not assigned, so, in retrospect, it is not possible to look into this question using these data. A second possible explanation is that the number of successful matings or services was lower for the undocked

FIGURE 3. LAMBS BORN OF EWES LAMBING FOR DOCKED AND UNDOCKED EWES FOR YEARS 1981-1986.



ewes which may have reduced the possibility that a given ova would be fertilized. The third is the possibility that more fat on the body or in the internal organs, as opposed to its presence in the tail, may have contributed to a higher ovulation rate. Movassagh (10) found greater uterine and ovarian weights for docked vs. undocked ewes. This finding should be further investigated in light of the low lambing rate of fat-tail sheep in general. Collectively, these studies suggest a number of ways in which reproductive performance of these sheep might be improved.

Table 1. Reproductive Performance of Docked vs Undocked Ewes

	No. ewe years	Body wt. of ewes kg	Percent Lambing	Percent Lambs born per ewe lambing	Average lambing date	Lamb survival %	Weaning wt. per day of age(gms.)
Docked	111	53.3	92.9**	1.234*	174.7**	78.5	273
Undocked	120	52.9	78.9**	1.125*	182.5**	80.1	274
LS Mean	-	-	85.0	1.177	178.9	79.3	273.5

* Significant at .05 Level of probability
** Significant at .01 Level of probability

Eating Quality of Meat from Fat-Tail Sheep

There is a widespread belief in many countries that the meat obtained from fat-tail sheep is preferred to that from other types. From the very earliest dates that these sheep were introduced to the U.S. one can find references to differing qualities of their meat. For instance, the following statements have been gleaned from early literature: "They produce the finest flavored mutton to be found" - (5) "Karakul mutton is preferred over any other breed -- there is not that musky taint to it that is objectionable to many" (11), "Karakul mutton is free from the "wooly taste" so often objectionable in our domestic breeds" (12), "There is no sheepy flavor to the meat, on the contrary it has a fine gamey touch --", "Being free of the wooly taste of our native sheep, the fat which is the butter of Central Asia, is ideal for cooking purposes" (12), "...they seem to be devoid of the strong mutton flavor that is so often objectionable --" (from letter a signed by Mr. H.E. Finney, General Manager, Armour & Co. in 1911). "We are advised that the lambs are particularly desirable, on account of being void of the mutton or musty taste." (from letter signed by A.B. Case, Armour & Co. in 1911).

All the above comments derive from people who had a special interest in promoting this type of sheep, or were probably made in response to the solicitation of people involved with promoting the breed. Two further comments of a more objective nature call attention to a more negative point of view. "...they have large fat tails--which are a waste from the standpoint of the packer, since his customers do not want this.." (6), "...they are rather angular in conformation and are not well developed in these portions of the carcass that yield the most expensive cuts of meat..." (7).

The widespread belief that the Fat-tail types differ from other types of sheep in the eating qualities of their meat persists to the present time in many parts of the world. For instance, a consumer survey conducted in Saudi Arabia as recently as 1984 indicates consumer preference ratings for the meat of the local Fat-tail types to be dramatically higher than those for meat from the Merino. There are potential alternative explanations for this expressed preference, but until this has been ruled out, the possibility of an actual difference in eating quality of the meat must be considered.

The authors of this report are aware (unpublished reports) of attempts to demonstrate differences in the eating qualities of meat of fat-tail origin without success.

In the present series of studies, two attempts have been made to look at this question. The first of these was reported by Edwards et al. (13) involving a comparison of Rambouillet (a type of Merino), Karakul and Blackface x Rambouillet crossbred lambs. This study was conducted using animals which had been maintained in the feedlot for a period of time to produce carcasses equivalent to U.S. Choice grade. Sensory panel ratings were obtained for loin chops and leg steaks from ram and wether lamb carcasses of each of the three breed groups. The results are shown in table 2. Perhaps as expected, the meat from carcasses of wether lambs tended to receive higher ratings than meat from ram lambs. Differences in sensory panel ratings for the three breed groups were not statistically significant, but such differences as did exist tended to favor the meat from Karakul lambs. The one general exception to this was in juiciness which is often an expression of intramuscular fat. Less intramuscular fat would be expected in meat from fat-tail animals. Ram lambs are expected to be leaner than wether lambs with a similar influence on juiciness ratings, and this proved to be the case.

Table 2. Effect of Gender and Breed of Lamb on Sensory Panel Characteristics of Loin Chops and Leg Steaks of Three Types of Sheep

	Gender		Breed Group		
Variable	Ram	Wether	Ramb.	Crossbred	Karakul
No. Animals	30	26	20	16	20
	LOIN CHOPS				
Tenderness*	5.2	5.7	5.2	5.5	5.7
Flavor	5.5[a]	5.9[b]	5.6	5.7	5.9
Juiciness	4.7	5.0	5.0	4.9	4.7
Overall palatability	4.9[a]	5.4[b]	4.9	5.1	5.4
	LEG STEAKS				
Tenderness	4.4	4.6	4.1	4.9	4.6
Flavor	5.4	5.6	5.4	5.4	5.6
Juiciness	4.6[a]	4.9[b]	4.8	4.7	4.8
Overall palatability	4.5[a]	4.9[b]	4.4	4.8	4.8

* Values represent taste panel ratings with the higher values being more desirable.

a,b Means on the same line with different superscripts are statistically different.

A second study (14) compared the palatability of lamb. mutton and goat meat from 3 types (or breeds) of sheep and two types of goats. Two groups, based on age and sex combinations, were also involved; these were young intact males and aged females. These groups were chosen to depict the most typical market animals that are derived from sheep and goat production systems in developing countries. In general, the animals were not fat and they had not been fed to attain specific U.S. grades. Palatability ratings were made on loin chops and leg steaks from which the exterior fat had been trimmed. It should be pointed out that this is not the style of cooking in many countries where a high level of consumption of sheep or goat meat occurs.

In the latter study the meat from fat-tail carcasses was not superior in palatability to that from other types of sheep, and differences in palatability, though small, tended to favor the cooked meat from Rambouillet carcasses. Meat from sheep carcasses was given higher ratings than that from goats. Surprisingly, however, the meat from young (male) carcasses was not superior in palatability (flavor, juiciness, tenderness) to that from aged females. This study involved both foreign (non-U.S.) as well as domestic (U.S.) sensory panels (groups of taste-testers) and there was a tendency (in some cases statistically significant) for foreign panelists to assign higher palatability ratings than did domestic panelists. This suggests that foreign panelists are less critical regarding the relative quality of sheep/goat meat than are domestic panelists and more acquainted with characteristic flavors and tenderness of ovine and caprine muscle and fat.

The carcasses involved in the latter study had a relatively high lean content compared to the fed lambs of the earlier study. Within these two studies, there does appear to be a tendency for the cuts from the fatter animals to receive higher ratings.

Collectively these two studies do not support to any significant degree, a claim for superiority of palatability of meat from Fat-tail sheep. In contrasting the two studies, there is a suggestion that if there is a difference it may be associated with the fat rather than the muscle component of the carcass. This would be expected since it is the fat that imparts unique flavors to red meats (15). In this connection, dock fat samples from the carcasses in the latter study were subjected to fatty acid analysis. Some of these results are shown in table 3 (16). The analyses included fatty acids ranging from C14 to C18, along with some unidentified fatty-acid peaks, and total saturated, and unsaturated, fatty acids are reported. A number of significant differences can be found in these data, but the interpretation or significance to be attached to these data is not clear. Young animals had a lower proportion of saturated fatty acids and a higher level of unsaturated fatty acids, but the reverse was definitely the case for the aged animals. This trend is even more marked in the case of the Karakul. Much of this wass due to the low level of C18:0 fatty acid in the fat from young Karakuls relative to that present in the fat from aged animals.

The authors of this report believe that these data do not provide a basis or explanation for any marked difference in palatability or acceptability of meat from fat-tail sheep. If this is the case, there appear to be two possible explanations; i.e., (a) that such a difference does not exist or (b) that the explanation is to be found in other than the muscle or in C:14 to C:18 fatty acid content of the adipose tissue.

Table 3. Mean values for fatty acid composition stratified according to age/sex and breed/specie

Fatty acid	Angora goats (n=8)	Spanish goats (n=7)	Rambouillet sheep (n=12)	Barbado sheep (n=11)	Karakul sheep (n=21)	Angora goats (n=17)	Spanish goats (n=13	Rambouillet sheep (n=13)	Barbado sheep (n=11)	Karakul sheep (n=10)
C14:0	3.88^{ab}	4.43^{a}	3.12^{bc}	2.15^{d}	2.74^{cd}	2.67^{a}	2.54^{ab}	2.20^{c}	2.05^{c}	2.25^{abc}
C15:0	0.55^{b}	0.58^{b}	0.53^{b}	0.56^{b}	0.85^{a}	0.64^{a}	0.56^{ab}	0.49^{ab}	0.46^{b}	0.52^{ab}
C16:0	26.40^{a}	26.74^{a}	22.78^{b}	19.26^{c}	21.87^{b}	27.18^{a}	24.50^{b}	23.08^{bc}	20.96^{c}	22.84^{bc}
C16:1	3.37^{ab}	3.67^{a}	2.44^{c}	2.61^{bc}	3.21^{ab}	3.76^{a}	3.73^{a}	3.19^{ab}	2.77^{ab}	2.62^{b}
C17:0	1.72^{b}	1.64^{b}	1.85^{b}	1.71^{b}	2.35^{a}	2.05^{a}	1.88^{a}	1.86^{a}	1.72^{a}	2.04^{a}
C17:1	0.44^{c}	0.61^{bc}	0.85^{bc}	1.15^{ab}	1.41^{a}	0.50^{a}	0.73^{a}	0.66^{a}	0.47^{a}	0.69^{a}
C18:0	25.98^{a}	22.44^{a}	20.81^{a}	22.45^{a}	14.80^{b}	28.75^{a}	26.76^{a}	27.50^{a}	30.46^{a}	29.47^{a}
C18:1	33.03^{b}	35.74^{b}	41.84^{a}	43.40^{a}	44.89^{a}	30.42^{b}	35.36^{a}	36.47^{a}	37.14^{a}	35.55^{a}
C18:2	3.44^{a}	3.29^{a}	4.25^{a}	4.06^{a}	3.80^{a}	2.09^{b}	2.15^{b}	2.99^{a}	1.99^{b}	1.65^{b}
Unident. peak	0.00^{b}	0.00^{b}	0.16^{b}	0.91^{ab}	1.58^{a}	0.00^{a}	0.15^{a}	0.00^{a}	0.35^{a}	0.47^{a}
Remainder	1.19^{b}	0.86^{b}	1.32^{b}	1.74^{ab}	2.59^{a}	1.93^{a}	1.61^{a}	1.70^{a}	1.63^{a}	1.92^{a}
Total sat.	58.53^{a}	55.82^{ab}	49.09^{bc}	46.13^{cd}	42.61^{d}	61.30^{a}	56.24^{ab}	55.13^{b}	55.64^{ab}	57.11^{ab}
Total unsat.	40.28^{b}	43.32^{b}	49.39^{a}	51.22^{a}	53.31^{a}	36.78^{b}	41.96^{a}	43.32^{a}	42.38^{a}	40.50^{ab}

abcd Means in the same row and for the same age and sex group bearing a common superscript letter are not different ($P<0.05$).

Previous quotations or statements included earlier in this report refer to the absence of a distinctive mutton odor or flavor which is often found in other types of sheep. It has previously been reported by Cramer et al. (17) that the mutton flavor is more prevalent in fine-wool breeds which on the world market provide the primary contrast or alternative to the Fat-tail. The Cramer et al. study also demonstrated a correlation between fineness of the wool and intensity of mutton flavor in the meat of lambs. Thus, there is precedent for breed differences in intensity of undesirable flavor. Also, in the work reported by Cramer et al. differences in the C:14 to C:18 fatty acid composition do not appear to provide a satisfactory explanation for differences in mutton flavor intensity. However, a recent report by Wong, Johnson and Nixon (18) suggest 4-methyloctanoic (hircinoic) acid as the source of "goaty" or "mutton" odor of the fat of sheep and goat carcasses; these odors were detected in the volatile compounds of cooked fat from these species. Also, Hornstein and Crowe (15) suggest that carbonyl compounds present in the fats are the primary source of differences in odor or flavor of lamb meat. Bartholomew et. al. (19) stated "mutton flavor is produced by the aroma from volatile compounds and the taste is produced by non-volatile compounds." " Compounds that appear to be factors in producing mutton flavor are lactones, heterocyclic volatile compounds, mercaptans, organic sulfides and 9 and 10 carbon, branched-chain acids" (Bartholomew et al.).

Another possible explanation for a preference for the meat of the Fat-tail types would be less fat intermingled with the carcass. Although the Fat-tail types might be expected to have lower intramuscular fat, it is difficult to visualize this as a major factor among people which have traditionally consumed sheep fat.

Thus there appears to be a clearly defined need to look for differences between major types of sheep in respect to odor or flavor of the meat, especially as these may be that associated with the fat of the animals.

Carcass Traits of Fat-Tail Compared to Other Types

Two studies utilizing limited numbers of animals have been completed involving a comparison of Karakuls with other types of sheep with respect to carcass traits. One of these studies has been previously reported (13); it demonstrated a carcass fat trim of 15.4% for Karakul as compared to 6.6% for the Rambouillet (see table 4). This large amount of fat trim resulted in as much as 7.5% lower yield of wholesale cuts from Fat-tail carcasses. This fat trim was largely that associated with the tail as is evidenced in table 4 by amount of fat trim from the leg and loin. The Karakul also had greater fat thickness over the 12th rib than did lambs of the other two breeds. Thus, at comparable weights, the total body fat of Karakuls is greater than that for the other two types of sheep. Another unreported study (figures 4 and 5) shows essentially the same results -- the Karakul has the large fat deposit in the tail, is fatter over the rack and is comparable in kidney and pelvic fat, with the result that 20% of the carcass was removed during fabrication as trimmable fat. O'Donovan et al. (20) reported a carcass fat percentage of 33.3% for Iranian fat-tail sheep. This high level of body fat is perhaps the major factor contributing to survival of these sheep in times of stress (for breeding ewes), but represents a very serious waste in terms of carcass value in

those countries which do not have a ready market for this type of fat.

Table 4. Effect of Breed of Lamb on Selected Carcass Characteristics

Carcass trait	Group			SD
	Rambouillet	Crossbred	Karakul	
No. observations	20	16	20	
USDA yield grade	2.7[c]	2.4[c]	3.0[d]	.63
USDA quality grade	11.1	11.5	10.9	1.05
Dressing percentage	52.6[c]	53.8[c]	56.1[d]	2.94
Carcass fat trim (%)	6.6[c]	6.7[c]	15.4[d]	2.21
Trimmed wholesale cuts (%)	78.9[c]	80.2[c]	72.7[d]	2.65
Fat trim from leg (%)	8.7[c]	8.1[c]	32.1[d]	3.69
Fat trim from loin (%)	9.8[c]	9.0[c]	21.0[d]	5.08
Ribeye area, 12th rib (cm^2)	14.3	14.7	14.2	1.91
Leg conformation score*	11.7[c]	12.7[d]	10.5[e]	.92
Fat thickness, 12th rib (mm)	3.2[c]	3.1[c]	4.4[d]	1.40

a,b Means on the same line for gender with different superscripts are different ($P<0.05$).

c,d,e Means on the same line for breed with different superscripts are different ($P<0.05$).

* Coded as follows: high prime = 15, avg. prime = 14, et cetera.

Effect of Docking on Growth and Carcass Traits

Method of Docking;

A portion of the lambs in the experimental flock were docked while others were left intact. The lambs were docked on the first or second day following birth. The method of docking consisted of placing a rubber band (elastrator ring) on the tail followed by cutting the tail at the ring 24 hours later. The lambs were given an injection of tetanus anti-toxin at the time the band was placed on the lamb, although, there was no evidence of a tetanus problem using this docking procedure. Fat-tail lambs have a thick tail at birth which grows rapidly, and thus it is important that docking be done early, as the nursing lamb deposits fat rapidly. Docking the lambs close to the tail setting reduces the fat deposition in the tail.

Death losses and the relative growth rates of the docked vs undocked lambs are shown in table 5. Differences between years, sex and type of birth were statistically significant. Differences in growth rate between lambs which were docked and those that were not docked were not significant, but when differences existed, they favored the docked lambs. Other researchers (21) have reported slower growth rates for docked animals. In this study, docked lambs had a higher death loss; although this difference was not significant, further research on this point seems warranted.

One trial has been completed in this series of studies comparing the carcass merit of docked vs non-docked animals (Table 6), and other similar studies can be found in the literature. From data presented earlier (figures 4 and 5) it can be seen that up to 20% of the weight of the carcass of fed fat-tail animals was as trimmable fat. Because a large portion of this fat trim was from the tail, it seemed pertinent to determine the effect of docking on amount of fat trim. As shown in

figure 4, docking markedly reduced the tail or dock fat trim from 6.5, to 1.7, percent of the carcass. This reduced the overall fat-trim in the carcass by five percent. In the latter study, docking did not increase the thickness of the external fat cover and only a marginal increased kidney and pelvic fat content. In another study, conducted by Joubert and Ueckermann (22), the docked animals showed a slight, but non-significant, increase in kidney and pelvic fat, but no increase in external fat cover thickness. Other studies (20 and 23) have shown an increase in subcutaneous and internal (kidney/pelvic) fat deposition, but such increase was not sufficient to compensate for the total reduction of fat in the tail. Sefidbakht and Ghorban (24) reported 16% separable fat of docked animals as compared to 27% for non-docked controls; these data suggest a reduced total fat deposition in docked animals. This should be advantageous to carcass value in all cases except potential market outlets where the price received for fat is equal to that of the carcass. Other work (25) has shown a tendency for increased intramuscular fat deposition of the loin in docked animals (i.e., 4.5% for docked vs. 4.1% for undocked animals).

Table 5. Least Square Means for Weaning Weight (kg) and Lamb Survival by Treatment Groups

Year	Type of Birth	Sex	Type of Tail	Wean Wt.	Lamb Survival %
1981 - 29.4[b]					
1982 - 30.9[b]	Single - 34.7[a]	Male - 34.8[a]	Docked -	33.4	84.3
1983 - 25.0[c]					
1984 - 39.6[a]	Twin - 28.1[b]	Female-31.5[b]	Undocked-	33.0	90.7
1985 - 39.4[a]					

Epstein (21) reports a total body fat content of undocked Awassi lambs at 14.0%, compared to 12.4% for docked lambs. These values are of interest in that this researcher reports much lower fat percentages. This could potentially relate to the breed used, but much more likely is explained by lower slaughter weights (approximately 27 kg as compared to 50+ kg in the Texas study). Observations indicate that fat stores increase, both in actual terms and as a percentage as the animal matures. This is true for all types of sheep, but much more so for the fat-tail types.

Table 6. Comparison of Rambouillet and Docked vs Non-Docked Karakuls with Respect to Certain Carcass Traits

Trait	Rambouillet	Karakul Docked	Karakul Non-docked
Dressing Percentage	54.03[a]	56.73[b]	57.13[b]
Cooler shrink, %	6.23	6.94	7.35
Fat thickness, 12th rib, inches	.15	.24	.27
Ribeye area (sq. in)	2.20	2.24	2.03
Total fat, %	9.00[a]	15.53[b]	19.76[c]
Rack fat, %	0.68	1.14	1.11
Dock fat, %	0.25[a]	1.68[b]	6.49[c]
Kidney/pelvic fat, %	4.44	4.34	4.00

FIGURE 4. COMPARISON OF PERCENTAGES OF RACK FAT, KIDNEY/PELVIC FAT AND DOCK FAT AMONG NON-DOCKED AND DOCKED KARAKULS AND RAMBOUILLET SHEEP

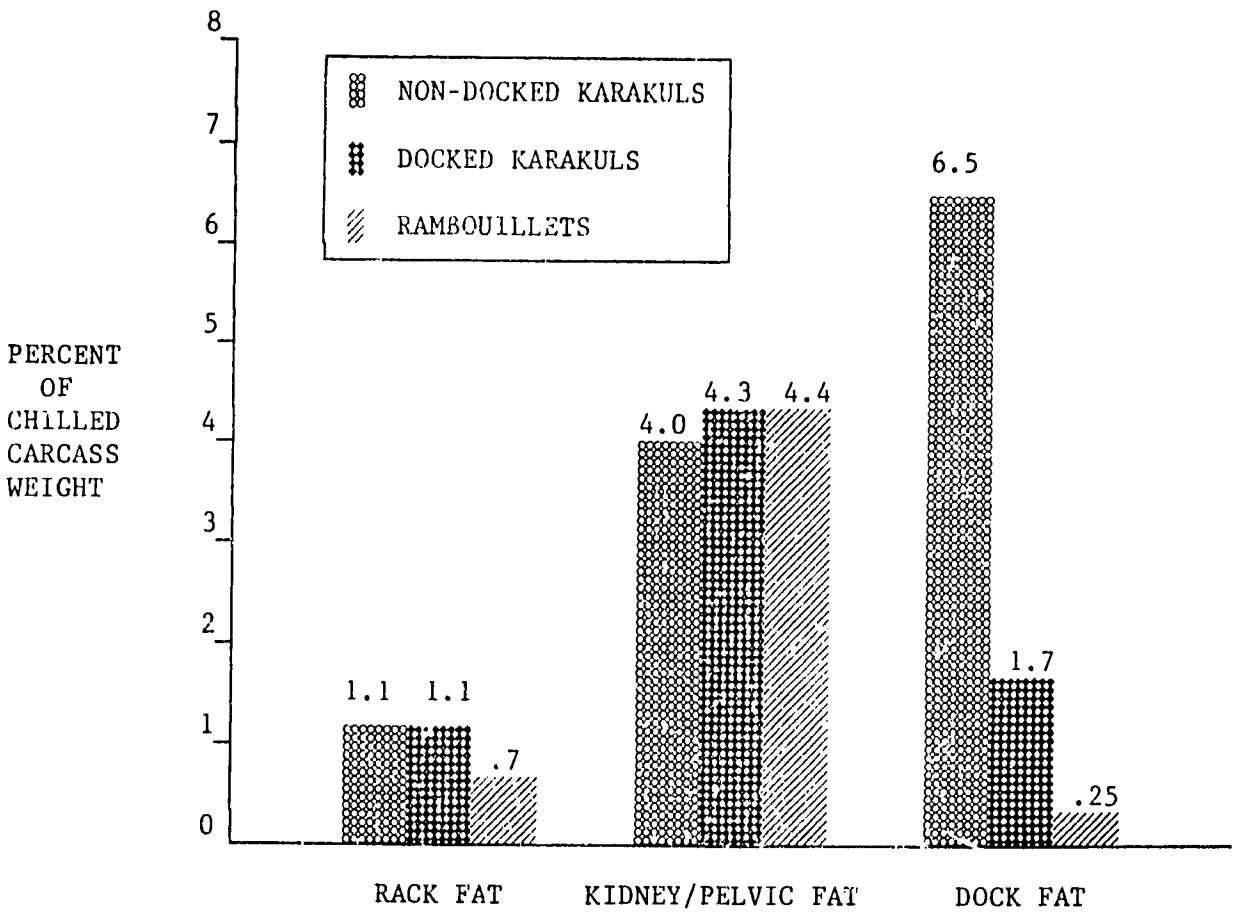
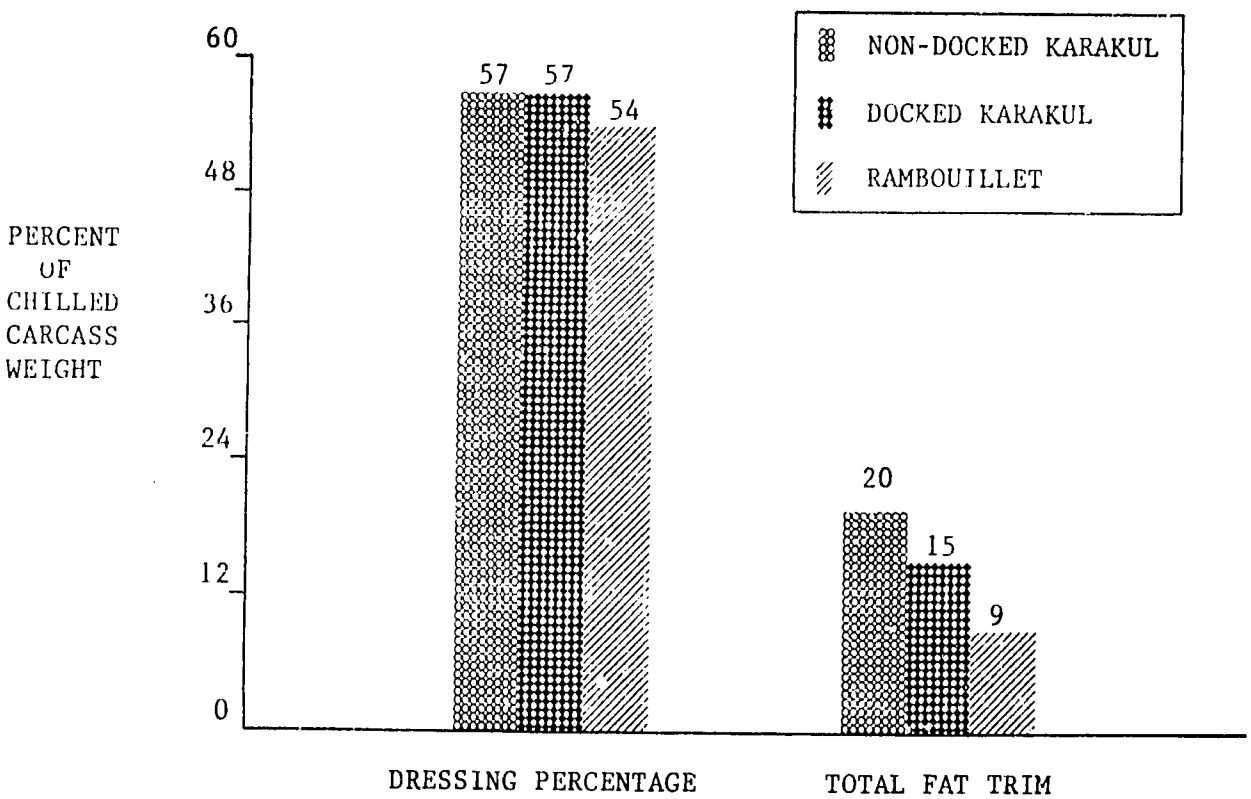


FIGURE 5. COMPARISON OF DRESSING PERCENTAGE AND TOTAL FAT TRIM PERCENTAGE AMONG NON-DOCKED AND DOCKED KARAKUL AND RAMBOUILLET SHEEP



What is the Significance or Explanation for the Accumulation of Fat in the Tail?

A phylogenetic explanation for the accumulation of fat in the tail must hold theoretical, as well as practical, interest. Most fat-tail sheep are located in arid regions which are subject to extended periods of feed shortage. In addition, such sheep tend to be concentrated in areas subject to great variation in body temperature between night and day or between seasons. Few fat-tail sheep are found in humid or tropical climates. This is generally explained in that animals in tropical environments do not need large deposits of fat, and climatic conditions do not encourage deposition of fat (i.e., total feed intake is reduced under conditions of high temperature stress). It has also been suggested that fat-tail animals suffer in humid environments because the skin covered by the tail flap does not dry out -- resulting in unsanitary or necrotic conditions.

In the simplest terms, an accumulation of fat in the tail must result from natural or artificial (that imposed by man) selection. There is actually a tendency for accumulation of fat in the posterior region in many breeds or species. For instance, there are several breeds of sheep characterized by deposition of fat around the rump. Thus, fat-tail sheep differ from other types of sheep only in the degree and specific location of their fat deposition. If man has actually selected for the fat tail it may be hypothesized that; (a) such animals were thought to be more adaptable or productive, (b) the meat of this type was preferred. or (c) in earlier periods, the fat of the sheep was needed for cooking, seasoning or for use in preservation of other food products. This use might be comparable to that made of pork fat by farm families in the U.S. in earlier years. A quotation cited earlier that the tail fat was "the butter of Central Asia, and is ideal for cooking purposes" emphasizes this point. There is an important distinction in that these sheep evolved and were used in the Middle East over thousands of years. In an arid or desert environment, animal fat (from sheep) could be collected much more easily if it was concentrated at one place in or on the body. The authors of this report are of the opinion that this is the most likely explanation for selection/propagation of sheep with this unique accumulation of fat. With the widespread availability and use of vegetable oils and changes in dietary habits, the fat tail is no longer in great demand and in many markets it is removed from the carcass before delivery to retail outlets. In some cases, it has almost no value or is used for industrial purposes at very low prices. Thus, heavy fat accumulation constitutes considerable loss or waste with up to 1/3 of the world's population involved. Many carcasses which are exported to the Middle Eastern market have the fat tail removed before shipment suggesting some resistance to the excess fat present there. In this case, however, the buyer can still identify the carcass as being of fat-tail origin.

On the other hand, if natural selection is the primary mechanism for the accumulation of fat in the tail, an explanation for the adaptive advantages must hold interest. The most common explanation is that the fat in the tail is necessary for the sheep to survive at times of feed scarcity during dry or cold periods. However, this is a very superficial explanation and has a measure of validity only if the accumulation of fat in the tail has advantages (in terms of speed or ease of catabolism) over fat placed at other sites on the body. This

has not been shown to be the case. Other potential sites for fat deposition are internal (kidney and pelvic region), subcutaneous, intermuscular and intramuscular. It could be theorized that presence of large amounts of internal fat interfere with the ability of the animal to consume large amounts of feed when it is available, or that subcutaneous fat would interfere with heat dissipation at times of heat stress. Both of these could possibly be true at some time or some place, but are these factors adequate to overcome the interference of the tail with reproduction under natural mating conditions or to take precedence over natural selection? A series of investigations (26) was carried out to compare Karakul with other sheep in terms of their response to heat stress, and to compare docked vs undocked animals. It might be expected that docking results in an increase in subcutaneous fat, and thus this comparison should provide some information on the question of tail fat deposition as a factor in dealing with heat stress. These data are shown in table 7, 8 and 9.

In summary, the Karakul sheep were less affected by temperature stress than Rambouillet, but were more stressed than meat-type (non-fiber producing) goats. In general, there was little difference between docked and undocked animals; however, in three of the four cases such differences as did exist favored the docked animals. Juma, Gharib and Eliya (27) found that docked fat-tail rams maintained significantly lower rectal temperatures and respiratory rates than control animals (not docked). Also, Juma and Dessouky (28) found that docking improved semen quality of rams. These studies do not support the theory that the accumulation of fat in the tail is beneficial to the animal in dealing with heat stress, and strongly indicate the reverse -- that docking is beneficial.

Table 7. Least Square Means for Body Temperature and Respiratory Rate of Rambouillet and Karakul Ewes

		Respiration rate	Rectal Temperature °F
Breed:	Karakul	151.3[a]	103.0
	Rambouillet	161.3[b]	103.2
Fleece:	Wooled	142.1[a]	103.0
	Shorn	170.5[b]	103.2
Tail:	Docked	150.0	103.0
	Not Docked	152.7	103.1

Another suggested potential advantage for accumulation of fat in the tail Is that a reduced internal fat storage would permit greater feed intake if intake became a critical factor. This would more likely be critical for the pregnant ewe, particularly for those carrying twins. Also, docking the ewe could theoretically increase the internal (kidney/pelvic) fat deposition (24). An experiment was conducted in which ewes of three breeds (Rambouillet, Karakul and Finnish Landrace), in late pregnancy, were provided ad libitum feeding of a mixed and pelleted ration. The Karakul group contained docked and undocked ewes. The ewes were kept on feed for a period of time after lambing to

Table 8. Least square means for respiration rate and body temperature measurements for five types of male small ruminants

	Rambouillet rams	Barbados Blackbelly rams	Docked Karakul rams	Fat-tail Karakul rams	Meat-Type Goat Males
	n=10[1,2]	n=10	n=10	n=10	n=10
Rectal Temperature (F°)	104.5±0.12[ab]	104.3±0.12[ab]	104.1±0.12[b]	104.0±0.12[b]	104.±0.12[b]
Respiration Breaths/min.	200.5±4.96[a]	167.4±5.09[b]	148.2±5.02[c]	143.6±4.96[c]	116.9±4.95[d]

[1] Leastsquare means with different superscripts in a row differ by (P<.05).
[2] Four observations per animal

Table 9. Least square means for respiration rate and body temperature measurements for six types of female small ruminants

	Docked Karakul ewe lambs	Fat-tail Karakul ewe lambs	Docked Karakul ewes	Fat-tail Karakul ewes	Barbados Blackbelly ewes	Spanish does
	n=5[1,2]	n=5	n=6	n=6	n=5	n=7
Rectal temperature (F°)	104.66±0.11[ab]	104.65±0.11[a]	103.94±0.09[b]	103.58±0.08[c]	103.44±0.09[c]	103.18±0.08[d]
Respiration rate	173.15±5.81[ab]	180.29±5.46[a]	141.72±4.35[d]	149.47±4.60[dc]	161.73±4.86[cb]	144.29±7.54[b]

[1] Least square means with different superscripts differ by ($P<.05$).
[2] 12 observations per animal

coincide with the early stage of lactation. Some of the results of that trial are shown in tables 10 and 11 and are expressed as total daily intake in grams and as a percentage of body weight. All data for ewes which produced more than two lambs were deleted from the data-set, because of marked breed differences in litter size. For instance, none of the Karakuls dropped more than two lambs. As expected, ewes ate significantly more feed after lambing; this is probably more an expression of need than of body capacity. Also, ewes with twin lambs ate more feed than did those with singles. This was much more marked after lambing than before. There is a distinct tendency for Karakul ewes carrying twin lambs to eat less feed before lambing. Breeds differed significantly from each other in total feed intake before lambing, but when feed intake was expressed as a function of body weight only the Rambouillets, which had lower intake, differed from other breeds. After lambing, Rambouillet ewes differed significantly from other breeds in both total feed intake and feed intake as a function of body weight. These data suggest that Karakuls have a higher level of feed intake, but the only marked difference is between Karakul and the Rambouillet when feed intake is expressed relative to body weight. It is known from other studies that Karakuls have a higher body fat content; thus, feed intake relative to physiological needs for maintenance would be more for the Karakuls.

Some of the Karakul ewes used in the latter study were docked and some were undocked. Comparative feed intake data contrasting these two groups are shown in table 12. The differences associated with gestation vs lactation and single vs twin births are similar to those evident in tables 10 and 11. Docked ewes consumed less feed, but the differences were not significant. A justification or explanation for this greater intake relates to possible greater internal (kidney/pelvic) fat deposition. Evidence supporting this point is variable (20, 22, 24).

Table 10. Total Feed Intake (grams per head per day) by Breed

	Finnish Landrace	Karakul	Rambouillet
Before Lambing			
Single	2178	2775	2421
Twins	2278	2537	2629
After Lambing			
Single	3352	3743	3470
Twins	4532	4159	4432

Table 11. Ratio of Feed Intake to Body Weight by Breed and, Number of Lambs

	Finnish Landrace	Karakul	Rambouillet
Before Lambing			
Single	$.040^{abc}$	$.049^{a}$	$.037^{a}$
Twins	$.043^{ab}$	$.041^{b}$	$.036^{a}$
After Lambing			
Single	$.061^{bc}$	.065	$.054^{a}$
Twins	$.070^{abc}$	.069	$.063^{a}$

Table 12. Total Feed Intake (grams per head per day) for Docked and Undocked Karakul Ewes Pre- and Post-Lambing Relative to Number of Lambs Born[1]

	Pre-Lambing	Post-Lambing	Overall
All ewes	2661.9	3670.7	3292.4
Docked ewes	2526.7	3659.4	3234.6
Undocked ewes	2786.5	3749.4	3388.3
Single births	2781.2	3506.6	3195.7
Twin births	2484.8	3934.6	3313.3

[1] Differences between pre- and post-lambing periods are statistically significant; other differences are not significant. Not all comparisons are completely orthogonal since date of lambing and number of ewes carrying twin fetuses could not be controlled. Data are included from a total of 22 ewes.

The Relation of the Fat-Tail to Adaptation to Arid Environments

It has been previously stated that this type of animal tends to be adapted to, or at least located in, arid regions, and, more specifically, to arid regions subjected to wide ranges in temperature where both heat or cold stress may be encountered. Limited data have been presented which suggest that such sheep handle hot weather better than do Merino types. Since fat-tail sheep would spend much of their time in environments with high radiant heat loads with little access to shade, it seems likely that their coarse fleece would benefit the animal in both hot and cold climates. The data presented earlier in tables 8 and 9 were collected with black animals whereas lighter-colored animals may have actually had a greater advantage with respect to radiant heat load. There is at least a theoretical basis for the belief that dark-colored animals would have an advantage in cold seasons (29). It was suggested earlier that the Fat-tail types of sheep do not possess any unique adaptations to humid environments. One of the suggested reasons for lack of adaptiveness to humid environments could be overcome by docking, and thus -- if they are to be produced in tropical environments -- they should be docked.

Carcass studies have shown that one difference between Fat-tail and other types of sheep, with which they have been compared, is a high level of total body fat content. It is suggested that this is the reason for their unique adaption to long periods of nutritional stress. The fact that they almost universally produce single lambs also probably contributes to ewe and lamb survival under conditions of nutritional stress, and contributes to the use of the ewes for partial milking following limited suckling or early weaning.

The high level of body fat could simply result from a higher metabolic priority for fat deposition as contrasted to other body functions -- including reproduction. However, limited data suggest an additional or alternative explanation. Data presented in tables 10 and 11 suggest a higher level of feed intake by the Karakul when given *ad libitum* access to feed. An additional study (30) which more directly addresses this point is summarized in table 13.

Table 13. Comparative levels of Feed Intake of Barbados Blackbelly (a tropically adapted hair-sheep), Karakul and Rambouillet Sheep

Criterion	Breeds		
	Barbados Blackbelly	Karakul	Rambouillet
No. of Animals	10	10	10
Live wt., kg.[1]	32.5[a]	57.0[b]	59.2[b]
Live wt., kg. 75[2]	13.6	20.7	21.3
Feed Intake, kg/day[3]	1.48[a]	3.44[b]	3.18[b]
Feed Intake, g/day/w^{75}	109.1[a]	166.0[b]	149.5[b]
Energy Intake, Kcal DE/day/w^{75}	308.0[a]	468.5[b]	422.1[b]

[1] Means in the same row with different letters are significantly different ($P<.05$)
[2] Live weight. kg.^{75} approximates the animals metabolic body size
[3] As fed basis

The differences in feed intake reported in table 13 are statistically significant only when contrasting the hair-sheep with the other two types. However, there is strong evidence of a difference in feed intake between the Rambouillet and Karakul and there is a need to further investigate this point. If this point is validated with further research, it will help explain the unique relationship of this type of sheep to sparse feed conditions in that a high level of feed intake and a high level of fat deposition at times when feed is available contribute to survival and productivity in times of stress. There appears to be a large difference between the tropically adapted animal and the fat-tail sheep in this respect.

It has been suggested (table 6) that docking results in a reduced total fat deposition, and thus this could result in reduced adaptation to periods of nutritional stress. The limited available data, shown in tables 1 and 5, do not show an adverse effect of docking on animal performance. However, the conditions under which these data were collected were not extreme and there is need to test their response under more extreme conditions.

The above stated theories provide a potential explanation for the superior adaptation of fat-tail sheep to arid environments, but do not provide an explanation for the accumulation of fat in the tail. Some potential biological advantages to this localization of the fat was suggested earlier, but the contribution of these factors would not appear adequate to overcome the interference with reproduction. This still suggests that man has selected for this unique accumulation of fat, but at the present this remains largely conjecture.

Crossbreeding with Fat-Tail Sheep

Under commercial conditions where they are produced, crossbreeding is very rarely practiced with the fat-tail sheep. Yet, there would appear to be very real advantages from crossbreeding. Assuming that the indigenous Fat-tail types have some adaptive advantages in the regions where they are produced, they are then well suited to the role of a dam line or dam breed. It may very well be questioned if there are alternative types which could serve this role. However, as pointed out

in other sections this report, there is considerable waste associated with the fat tail at the market place.

Few crossbreeding studies have been reported involving fat-tail sheep, and still fewer of these reports contain carcass data. For instance, Mavrogenis and Louca (31) reported increased weaning weights in crosses of Cyprus fat-tailed, Chios and Awassi sheep. Makarechian, Farid and Sefidbakht (9) reported that lambs sired by either Corriedale or Targhee, out of three different breeds of Iranian fat-tail ewes (Karakul, Mehraban and Naeini), grew faster than did purebreds of any of these breeds. Fox, Choueiri and Chabaan (32) successfully increased lambing rates over Awassi controls by crossing with the Chios. One study in the current series (33) involved growth and carcass traits of docked 1/2 Karakul (Karakul x Rambouillet) lambs in comparison with a number of other breeds (see table 14 and figure 7). Karakul-sired lambs tended to have a slower growth rate than all others with which they were compared except for the Barbados Blackbelly. In respect to carcass traits, lambs sired by Fat-tail rams had a higher dressing percentage (59.0% compared to 54.7 for Rambouillet). This no doubt derived from the fact that they were fatter; this was evidenced by their greater fat thickness over the loin and greater body wall thickness; however, they did not have an increased amount of kidney and pelvic fat. The fat trim from the tail and dock was 1.93% for the ½-Karakul as compared to 0.63% for the Rambouillet. The average carcass weight of the Karakuls in this study was 24.1 kg resulting in a 0.47 kg of fat trim from the tail. The necessity of trimming this amount from the carcass in order to move to retail channels would no doubt be dependent on the market. However, these data suggest that the combined practices of crossbreeding and docking largely eliminate the wastiness of pure, intact Fat-tail types. However, it should be pointed out that these docked crossbred animals are no doubt fatter than finewool or blackface crossbred types.

Table 14. Comparison of Growth and Carcass Data for Karakul Cross Lambs Compared to Other Types

	Rate of Gain (g)	Dressing[1] (%)	Fat Thickness (mm)	Body Wall Thickness (mm)	%K-P fat	% Tail Fat Trim	Fat Firmness[2]
Rambouillet	251	54.7	.174	1.99	4.43	0.63	3.36
Suffolk & Hampshire X Rambouillet	254	56.8	.231	2.33	3.57	0.67	3.89
Karakul X Ramb.	237	59.0	.320	2.64	4.35	1.93	3.08
Barbados Blackbelly X Rambouillet	179	55.7	.245	2.22	6.17	0.95	3.94

[1] Dressing percent after approximately 18 hours shrink
[2] Scores assigned on 1-5 basis with the higher values being more white and firm.

Summary and Conclusions

Fat-tail sheep are thought to make up as much as 1/3 of the world's sheep population, and are almost certainly the most important of all sheep in terms of the contribution they make to meeting man's need for food and fiber. Most of those belonging to this general group are triple-purpose animals producing meat, milk and fiber. This type of sheep is also important in respect to world trade in sheep meat since

6A 6B 6C 6D 6E 6F

Figure 6 A-F. Example carcasses of various breeds and crosses
6A - Karakul carcass
6B - Docked Karakul (this carcass was derived from a different experimental group)
6C - Trimmed fat-tail carcass (this is the form in which many carcasses are marketed)
6D - Karakul X Rambouillet Crossbred
6E - Docked Karakul X Rambouillet Crossbred
6F - Rambouillet Carcass

some of the major importing countries (in the Near East and Persian Gulf) are located in areas where consumers are accustomed to consuming the meat from Fat-tail types. Likewise, and perhaps as a result of close proximity to the above markets, some major exporting countries (i.e., Turkey) produce this type of sheep.

Fat-tail sheep tend to be concentrated in arid regions, and more specifically in arid regions which are also subject to wide variations in temperature. These sheep tend to be concentrated in the Middle East and North Africa, but they also inhabit parts of Africa and Asia. They are seldom found in humid or tropical areas. They are obviously adapted to arid regions, but they are not totally unique in this aspect as goats and some types of thin-tail sheep can be found intermingled with the Fat-tail types. In addition to the fat tail and any unique adaptive advantages, these sheep also produce carpet wool and generally have low twinning rates; however, they have high survival rates for both lambs and ewes.

An explanation for the unique adaptation of these animals and to the fat-tail trait must hold practical as well as theoretical interest. Our research indicates that, under comparable conditions, these animals have markedly higher total body fat content than others with which they have been compared, and that it is this total body fat, rather than its unique location in the tail, that contributes to the animals survival in times of feed scarcity. This high body fat content no doubt derives in part from a high metabolic priority for fat deposition. Also, data presented in this report suggests that this type of animal may have the ability to consume a larger amount of forage than do other types of sheep when forage is available, and thus this contributes to fat storage.

What is the explanation for the unique localization of fat in the tail? This pattern of fat distribution may be explained as being due to artificial (imposed by man) selection or natural selection. The authors of this report suggest that the former is the case, but this remains conjecture at the present time. If this is the case, man likely selected for this pattern of fat deposition in order that it could be removed and used for cooking, seasoning, preservation, etc. On the other hand, if natural selection is the explanation, it might be theorized that this pattern of fat deposition contributes to improved heat adaptation by reducing subcutaneous fat deposition or increased feed intake through reduced internal (kidney/pelvic) fat deposition. These points have been investigated in the present study. It can be shown that the Fat-tail types are less stressed in direct sunlight than other types of sheep with which they were compared (i.e., Rambouillet). Since docking of the animal results in a redistribution of some of the body's fat it might be expected that docked animals would be less heat-tolerant. In this study, and others, docked Fat-tail types have been compared in respect to their response to direct sunlight. The conclusion from these studies are that docked animals are actually cooler. This tends to rule out improved thermongulation as a result of reduced subcutaneous fat deposition as a potential explanation for the existence of the fat tail. In these studies, the Fat-tail types appear to have high levels of feed intake and the non-docked animals appeared to have higher levels of intake than docked animals. Thus, this potential explanation would appear to have more validity.

The fat tail, at least on the ewe, has a number of potential implications with respect to reproduction. It is generally recognized

that producers of this type of sheep utilize a higher ram to ewe ratio and that more mature rams are required. Also, it is not unusual to practice artificial insemination or to assist the rams in mating. The impediments to mating can be removed by docking of the ewe lambs or by changing to another genotype. Data generated in this series of studies suggest a higher percentage of ewes lambing and a higher lambing rate if the fat tail is removed. This would also benefit the industry by permitting crossbreeding to rams of another breed. Thus, a number of potential advantages relating to reproduction can be realized by removing the tail. This can be done quite effectively by docking. In limited studies in this series, the docked ewes did not suffer any disadvantages over a lifetime of production, but this needs to be tested further under more adverse conditions.

Carcass value is markedly lower in the Fat-tail types. It has been shown that as much as 20% of the carcass weight must be removed as fat trim to meet market demands. Types of sheep that are not o Fat-tail types generally have lower proportions of body fat and their fat is more uniformly distributed eliminating the need for trimming. This wastiness of the carcass can be reduced by docking or by crossbreeding and these two practices combined largely eliminate the excessive fat deposition at this anatomical site (in and around the tail).

Crossbreeding offers other advantages including increased growth rate and, possibly, increased lambing rates. The latter may or may not be advantageous depending on the management systems, particularly with reference to harvesting milk for human consumption.

There is a widespread belief that the meat from fat-tail sheep has better eating qualities than that from other types of sheep, particularly those of the Merino types. Studies included in this report do not confirm this. Palatability ratings of chops and roasts from lean or trimmed cuts do not show a significant or consistent difference between breed groups. It is suggested that there may well be a palatability difference that is associated with fat per se inasmuch as the distinctive flavor and aroma of meats, especially for sheep meats, associated with volatile compounds inherent to, or stored in, the fat of adipose tissues. The possibility of breed differences in this respect warrants further study.

These data suggest that, collectively, there are opportunities to make very marked improvement in the productivity of up to 1/3 of the world's sheep populations. These improvements can be made through improved reproductive rates, improved growth rates and improved carcass values from reducing waste associated with excessove fat trim. When treated additively these could very well result in more than a 30% improvement in total productivity/profitability of the sheep enterprise.

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