

3. MATERIALS AND METHODS

3.1. Experimental animals

Animals involved in this study were part of the animals produced during the period of a joint crossbreeding programme between the University of Malaya and the Humboldt University of Berlin (1990-1996), and later (under the programme was financed by IRPA (Intensification of Research Under Priority Areas) of the Malaysian Ministry of Science, Technology and Innovation) the animals were bred, produced and housed at the University of Malaya's Experimental Farm under intensive type of management.

Chapter 3

MATERIALS

AND

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The initial 60 Cameroon males and forty females were purchased from local farmers but later most of the Thai Long Tail sheep were obtained from the Department of Veterinary Services' farms. Cameroon semen were initially imported to initiate the cross with Thai Long Tail females by means of artificial insemination but due to the low conception rate, three live Cameroon rams and two Cameroon females were imported from Germany. Although the project started in 1990, the F_1 genotypes were produced in mid-1991. Crossbreeding for the production of the various genotypes was later done mainly by natural matings.

The Cameroon males were mated with the Thai Long-Tail females to produce the first filial generation (F_1), consisting of 50% Cameroon and 50% Thai Long Tail genes. Inter-se matings between the F_1 and F_2 crossbreeds were done to produce the second filial generation (F_2) and the third filial generation (F_3). Selection for hairy sires and ewes was done in order to develop further the hair gene expression in the subsequent generations. F_1 males were mated to the Thai Long Tail females to produce backcross 1 (BC₁) and the Thai Long Tail males were mated to the F_1 females to produce backcross 2

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The initial flock of two local Thai Long Tail wool sheep males and forty females were purchased from local farmers but later most of the Thai Long Tail sheep were obtained from the Department of Veterinary Services' farms. Cameroon semen were initially imported to initiate the crossbreeding of the Thai Long Tail females by means of artificial insemination but due to the low conception rate, three live Cameroon rams and two Cameroon females were imported from Germany. Although the project started in 1990, the F_1 genotypes were only successfully produced from mid-1991. Crossbreeding for the production of the various genotypes was later done mainly by natural matings.

The Cameroon males were mated with the Thai Long Tail females to produce the first filial generation (F_1), consisting of 50% Cameroon and 50% Thai Long Tail genes. Inter-se matings between the F_1 and F_2 crossbreds were done to produce the second filial generation (F_2) and the third filial generation (F_3). Selection for hairy sires and ewes was done in order to develop further the hair gene expression in the subsequent generations. F_1 males were mated to the Thai Long Tail females to produce backcross 1 (BC_1) and the Thai Long Tail males were mated to the F_1 females to produce backcross 2

(BC₂). The backcrosses only involved the F₁ and the Thai Long Tail because the aim was to select the genes for bigger size from the Thai Long Tail breed, and to see the dominance of the hair gene in the backcross generation with the expected ratio of 1:1 of heterozygous genes expressing a partially hairy coat and a recessive homozygote expressing a woolly coat (Figure 3.1).

The Cameroons (C) were also naturally mated to increase their numbers for the purpose of genotype comparison for this study. The number of Cameroons produced and involved in this study is small because the genotype was used as a sire line to produce the first filial generation (F₁ crossbreds) by crossbreeding via natural matings with the Thai Long Tail females. The five purebred Cameroons that were imported from Germany were not included in the data because their individual data from the date of birth to the date of their arrival in Malaysia were not available. The Cameroon data that were used in this study were taken from the Cameroon hair sheep that were produced in the nucleus herd of the University of Malaya. Therefore, their numbers were small.

The number of other animals involved in the study were few not only because of the controlled development of the subsequent purebred and crossbred genotypes, but also due to stabilizing the size of the flock in the nucleus herd to 200 – 250 heads, which can be supported by the limited feed resources and housing facilities available in the University farm. Therefore, the number of animals produced was controlled based of the number of available selected sires and ewes in the breeding programme. Animals that had reached 13 months of age and not selected as breeding males and females were either sold to farmers or slaughtered for obtaining carcass data or for sacrifices to meet the demand of religious ceremonies. Animals that were infected by diseases and cannot be cured were culled immediately.

Studies on the reproductive performances of the various genotypic groups involved the females that had reached maturity and the ewes used for the production of

the purebreds (Cameroon and Thai Long Tail) and the crossbreds (F1, F2, F3, BC1 and BC2). Male reproductive performance and semen characteristics were studied in another PhD project and therefore is not included here.

Figure 3.1 shows a schematic diagram of the crossbreeding programme and the development of the various genotypes with respect to the inheritance of the hair and wool genes.

3.2 Data collection and sample size

The data utilized in the evaluation of growth, body conformation and reproductive performance were recorded from the animals born in the University of Malaya research farm from 1990 to 1997.

The sample size of the genotypes included in the study is shown in Table 3.1. The number of animals involved in the growth, body conformation and reproduction studies were shown in the results for every parameter that was analysed.

3.3 Breed description

3.3.1 Cameroon hair sheep

The breed is said to have originated from South Africa. Generally the Cameroon is characterized by a short, smooth, glossy body lining and hairy coat cover (Plate 3.1 and Plate 3.2). However in some animals, traces of fine, soft and woolly undercoat can still be detected growing through the uppercoat. This will either be completely shed off as the animals get older or may remain behind like a saddle shaped pelage on the dorsal part of the body. The males have a prominent long, thick and hairy throat ruff and a pair of horns that bend backwards almost reaching the area around the jaws. The females are all polled.

Cameroon (C) hair sheep
HH

Thai Long Tail (TLT) wool sheep
hh

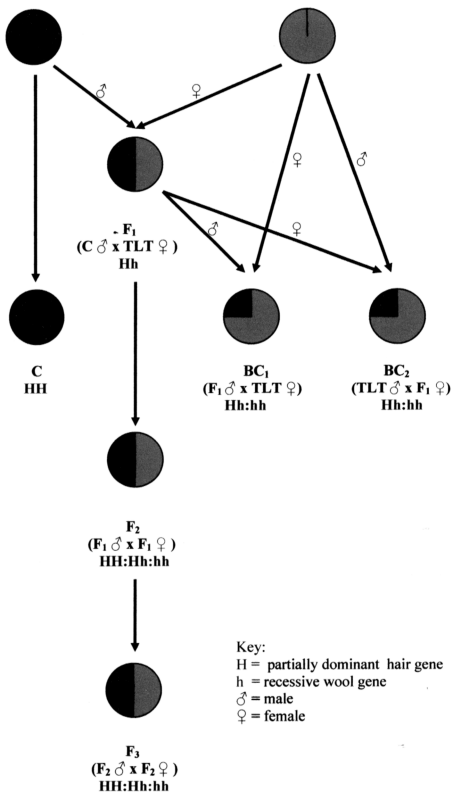


Figure 3.1 Schematic diagram of the crossbreeding programme and the development of the various genotypes

Table 3.1 Sample size of the genotypes included in the study

Genotypes	Symbol	Number of animals	Types
Cameroon	C	8	Hair sheep purebreds
Thai Long Tail	TLT	113	Wool sheep purebreds
C x TLT	F ₁	176	Crossbreds
F ₁ x F ₁	F ₂	92	Crossbreds
F ₂ x F ₂	F ₃	29	Crossbreds
Backcross 1 (F ₁ males x TLT females)	BC ₁	35	Crossbreds
Backcross 2 (TLT males x F ₁ females)	BC ₂	40	Crossbreds
Total		493	

The coat colour is usually brown, black or tan with some combination of white. A black belly can be found especially on the females. The tail is short, hairy and slightly bend and the ears are usually short.

3.3.2 Thai Long Tail wool sheep

The Thai Long Tail wool sheep, which is also known as Siamese Long Tail, is believed to have originated from Myanmar and Thailand. The Government of Malaysia had imported a large number of these animals into the country and distributed them to local farmers and breeders. After several generations, the Thai Long Tail is considered as one of the local wool sheep breeds of Malaysia.

The breed is characterized by its long, thick, coarse wavy wool throughout the body with short coarse wool on the neck, belly, hind legs and the head while the throat and the fronts legs are covered with kemp wool (Plate 3.3 and Plate 3.4). All the animals have a long, woolly tail, almost reaching the ground. Shearing has to be done at least twice a year to reduce heat stress, disease prevention and for management purposes.

3.3.3 F₁ crossbred (Cameroon x Thai Long Tail)

The F₁s' (Plate 3.5 and Plate 3.6) are the crossbreds of the Cameroon hair sheep and the Thai Long Tail wool sheep. The genotype has the genetic combination of 50% Cameroon and 50% Thai Long Tail. The lamb coat looks similar to the Cameroon lamb but as the lamb gets older the coat consists mainly of kemp fibres /wool forming the uppercoat with fine wool in between. The shedding process started from around six months of age but varied individually. Lumps of wool or matted kind of wool could be seen hanging around the body before they were completely shed off. The more wool is shed the more hairy the animals appear. The adult F₁ crosses usually have kemp wool

(50% of hair and 50% of wool) due to a heterotic effect or are of the completely hairy type, which is believed to be due to a dominant single hair gene effect.

The coat colour is usually light or dark brown, a mixture of brown and white, or brown with black belly. Black belly is very common in the females. The ears are horizontal but slightly longer than the pure Cameroon. The shape of the head is slightly convex.

3.3.4 F_2 crossbred ($F_1 \times F_1$) -

This genotype resulted from the inter-se matings of the F_1 crossbreds with the hair expression in the ratio of 1HH: 2Hh: 1hh that is one homozygous genotype for hair type, two heterozygotes for hair and wool genes and one homozygous genotype for wool gene. The fleece appearance of the F_2 resembles that of their F_1 parents. Some animals were also found to have the smooth body lining hair coat like the Cameroon. In general, the genotypes appeared to be less wooly than the F_1 and none showed the wool characteristics of the Thai Long Tail (Plate 3.7 and Plate 3.8).

3.3.5 F_3 crossbred ($F_2 \times F_2$)

This genotype was produced by inter-se matings between selected hairy parents from the second filial generation (F_2). In this generation, the segregation of the hair and wool coat varied further and the number of animals showing the wool coat became less. Variation of the hair coat varied with respect to the choice of parents. Hairy parents would produce lambs with more hair while the parents who showed some expression of wool cover would produce offspring with different hair type. Since selection was made prior to the matings, most of the F_3 genotypes were hairy type but there were some which

also showed the wool cover of the heterozygous type but this was very much less dense than in the pure Thai Long Tail (Plate 3.9 and Plate 3.10).

3.3.6 Backcrosses

Backcross animals were produced by crossing back the F_1 progenies to either one of their parents. In this study, F_1 males were mated to the Thai Long Tail females to produce the backcross 1 (BC_1) and reciprocal crosses between the Thai Long Tail males and F_1 females produced backcross 2 (BC_2). Most of the animals of the two backcross groups had fleece and kemp wool but not as dense as in the pure Thai Long Tail. The ratio of segregation would be 50% - 50%. This was expected as they had the gene combination in the ratio of 50% hairy and 50% wool (Hh:hh). However the degree of expression of the single hair gene in the HH group was not as prominent as in the F_1 crossbreds (Plate 3.11 and Plate 3.12).

3.4 Management of animals

All the animals involved in this study were obtained from the University of Malaya's experimental farm where they were kept under an intensive zero-grazing management system. Every morning prior to grass, concentrate pellets were given at a rate of approximately 2% of the body weight of the animal or a minimum of 250 gram per head. Later, freshly cut Napier grass was provided to the feed trough at an approximate amount of five kg per head (approximately 2% of dry matter content, on an average basis). Water and mineral salts in the form of salt licks were provided ad libitum. Deworming was done once in six months or sooner based on the faecal analysis of the



Plate 3.1 Cameroon hair sheep (male)



Plate 3.2 Cameroon hair sheep (female)



Plate 3.3 Thai Long Tail wool sheep (male)



Plate 3.4 Thai Long Tail wool sheep (female)



Plate 3.5 F_1 crossbred (male)



Plate 3.6 F_1 crossbred (female)



Plate 3.7 F₂ crossbred (male)



Plate 3.8 F₂ crossbred (female)



Plate 3.9 F₃ crossbred (male)



Plate 3.10 F₃ crossbred (female)



Plate 3.11 Backcross (male)



Plate 3.12 Backcross (female)

animals. Sick animals would be identified and immediately isolated from the rest of the animals by putting them into the sick pen(s). Nursing was done by the farm staff but serious cases would be referred to the veterinarians or the animal diagnostic laboratory of the Veterinary Department, Petaling Jaya, Selangor for further treatment. Weak animals and animals that cannot be cured from diseases were usually culled. Hoofing was done routinely and shearing once a year.

3.4.1 Housing

All the animals involved in this study were housed in wooden sheds with zinc roofing and the slated floor was raised up to about 1.5 meter from the cemented ground. The sheds were equipped with wooden feed troughs and drinking basins. Drinking water and salt licks in the form of mineral blocks were supplied *ad libitum*. The sheds were also lighted at night.

The animal sheds were designed with several pens, which could accommodate separately breeding males, breeding females, weaned males and females, and lambs. Single pens or individual pens were provided to expecting ewes until they weaned the respective lambs and to selected male breeders. Empty pens were reserved for sick and problem animals.

The animals were grouped into breeding males and females (9 months and above), and weaned males and females (3-9 months). Full measures had been taken to avoid accidental matings due to the breeding animals escaping into the opposite sex's pens. Unweaned lambs were kept with their mothers until weaning at 90-days of age.

3.4.2 General husbandry

3.4.2.1 Breeding males

Weaned males, which had reached the age of 9 months and showing mating behaviour and sexual advancement, were considered adults and transferred into the breeding males' pens. They were trained to mate. Mating with the females were allowed when they were ready to do so. Some were trained as teaser males to test females on heat and to increase their libido. Castration was not practiced in this farm. Occasionally the horns of the males would protrude onto the side of the jaw and had to be cut. Good breeding males would be selected for breeding and for the development of the required genotypes while the poor breeding males and that of the unwanted genotypes (woolly) would be sold or slaughtered. Semen collection and evaluation were done frequently to check male fertility and breeding ability.

3.4.2.2 Breeding females

After weaning at 90 days of age the young females were transferred to the females' weaning pens. They were allowed to grow in the weaning pens until they reached puberty, which was determined, after the young females were detected for their first oestrus.

Generally, oestrus was detected routinely twice a day, once in the morning and once in the evening. Oestrus was detected by allowing a teaser male to enter the females' breeding pens. Sexual and mating behaviour of the aroused ram and the female on oestrus, together with the appearance of vaginal discharge confirmed that the female was on oestrus. Oestrus was tested again after about six-hour interval and recorded.

Females, which had been detected for oestrus for the first time, was only mated after the second cycle of oestrus. Once oestrus had been detected, the females were mated to the to the sires of the required genotypes. A reproduction schedule was prepared to plan the matings for the production of the genotypes and at the same time to avoid matings between siblings or inbreeding. A strict breeding record was therefore a must.

Mating was done on the day when the female was detected for oestrus. Both animals were taken out from the breeding pens and allowed to mate naturally. Usually the ram was allowed to service twice. If the female showed a sign of oestrus on the following day or in the next cycle (after 19-21 days), she would be mated to the same male again.

3.4.2.3 Pregnant and lactating ewes

Breeding females were tested for heat every morning by allowing the teaser males to enter their pens. Ceasation of oestrus for three consecutive cycles was taken as an indication of pregnancy. Enlargement of the udder and abdomen was also considered as an indication of pregnancy. A sudden increase in body weight gain after the third cycle confirmed that the animal was pregnant. Sometimes palpation was also done to detect pregnant ewes because unlike goats, it was very common that sheep showed silent heat. The sheep could be pregnant even though she showed a sign of oestrus on the following cycle or several cycles after she had been mated.

After about four months in gestation, pregnant ewes were transferred from the breeding pens to individual pens in the lambing shed. Prior to that, the pens were cleaned thoroughly and disinfected. The expecting ewes were given individual supply of pellets, grass, mineral salt licks and drinking water. The ewes were closely observed for signs of parturition especially a few days prior to their expected due date. Once the ewe was in distress and showing signs of parturition, a sack would be laid on the floor of the pen for

the comfort of the ewe and her lamb(s) during and after lambing, to prevent the newborn(s)'s legs from slipping between the slated floor and for warmth. The ewes were also observed for lambing problems such as difficult delivery, stuck placenta and the like.

The mothers were weighed after the placenta dropped down or within 24 hours of parturition. The placenta was usually collected and buried while the sacks were changed every day until about a week.

3.4.2.4 Care of the newborn to weaning

As soon as the lamb was born the mother was allowed to lick and clean the lamb until the lamb was dry and could stand by itself. The sex of the lamb was determined and then the lamb was weighed. The umbilical cord up to around the navel area was sprayed with iodine solution for disinfection. The lamb was observed for its ability to suckle the colostrum as well as to observe whether the mother had enough milk to feed the lamb. This could be notified by the size of its udder and the number of lambs born. In cases where lambs were born as triplets and quadruplets, and for weaker lambs, they were usually given bottle-feeding, to supplement the milk supplied by their mother. The milk could either be extracted from the same mother, from another lactating mother or from commercial milk powder. Sometimes the lambs were allowed to suckle from a foster mother but very often they were rejected.

Tagging was done when the lambs were about 14 days or two weeks old. Each lamb was given an ear tag carrying the lamb number. The males were usually tagged on the right ear while the females on the left and the number would be maintained until adulthood. The serial numbers and the colour of the ear tags would denote the genotype of the lambs. Lost tags due to scratching or accidents would be replaced by tags carrying the same number and colour.

The lambs were weaned at the age of 90 days old. The lambs were weighed before transferring them to weaning pens in accordance with their sex.

3.4.3 Feeding

Feeding of all the animals under study in the University of Malaya's farm was based on the cut and carry system. The farm had allocated land for cultivating Napier grass (*Pennisetum purpureum*) which would be harvested and supplied as fresh Napier grass to the sheep as well as to other animals in the farm. A constant supply of fresh and young Napier grass was ensured by a four-week crop-rotation. Grass that was cut in the morning was left to dry near the sheds for about an hour, before placing them in the feeding trough. This was to ensure that the grass was not too wet, thus reducing the chance of the animals getting diarrhea, bloat and worm problem. Fresh Napier grass was given to the sheep twice daily, once in the morning and once in the afternoon. During dry spells when the amount of fresh grass supplied was not sufficient, commercial grass pellets were purchased to meet the daily requirements.

Concentrate pellet was supplied to the animals as a supplement to the grass. The amount given was about 200 gram per adult animal and 400 gram per late pregnant and lactating ewe. The weaned lambs were also given pellet at about 200 gram per lamb. The pellet was given once in the morning but it was also supplied when there was not enough grass available for the day.

The pellet was produced in the University of Malaya's feed mill. The raw materials used usually consisted of palm oil sludge (28%), palm kernel cake (12%), broken maize (18%), rice bran (18%), soya bean meal (10%), yeast (7%), molasses (5%) and limestone (2%). These ingredients were purchased from local suppliers. There were variations in the ingredients and their percent weights, due to the non-availability of

Table 3.2 Composition (%) of the concentrate pellets used in the University of Malaya's farm

Ingredients	Weight (%)	Crude Protein Content (%)	Fibre Content (%)
Palm oil sludge	28	3.89	9.32
Palm kernel cake	12	1.73	1.34
Broken maize	18	1.48	0.52
Rice bran	18	2.23	1.12
Soya bean meal	10	4.26	0.54
Yeast	7	3.03	0.07
Molasses	5	-	-
Limestone	2	-	-
Total	100	16.62	12.91

certain ingredients at certain periods of the year. The composition of the concentrate pellets is given in Table 3.2.

3.4.4 Health and hygiene

The health and hygiene of the animals were closely administered by having regular cleaning procedures. The cemented ground floors of the sheds were washed with water twice a week and disinfected regularly. The slated wooden floor of the pens, feeding trough and water containers were swept every morning, washed with water once a week. The floorings and the pens were thoroughly washed and disinfected regularly, especially before shifting and transferring the animals to their respective pens.

Shearing of the Thai Long Tail and the wooly animals were done once a year. Hoof and horn trimming were done whenever necessary. Other health and disease prevention procedures such as faecal analysis for parasites, feed and water analysis, veterinary services and the like was also conducted whenever necessary or when an outbreak of disease was suspected to occur in the farm.

3.4.5 Matings

Matings of animals to produce the various genotypes were mainly done by natural matings even though in the very beginning artificial insemination (A.I) was attempted. The main problem of A.I was the low conception rate and therefore natural mating was preferred.

After the ewes had been identified for oestrus, the respective sires were also determined. Both the animals were taken out of the group pens and allowed to mate naturally. Mating was satisfied after the ram has successfully injected the semen inside the vagina of the ewe with a sudden jerk, followed by traces of semen on the ram's

genitalia, on the vulva of the ewe or a few drops of semen dropping onto the floor. The ram was allowed to rest until it became aroused again for a second mating. This usually took about 5-15 minutes depending on the libido of the rams.

3.5 Traits under study

The traits involved in this study were growth, body conformation and reproductive performance of the Thai Long Tail wool sheep, Cameroon hair sheep and their crossbreeds (F_1 , F_2 , F_3 , BC_1 , BC_2). Data for all the traits were collected from all the animals that were produced in the farm, and kept in Excel data sheet.

3.5.1 Growth measurements

Growth measurements of all the animals in the sheds were measured routinely from birth to adulthood and as long as the animals were kept in the farm.

3.5.1.1 Birth weight

Birth weight is the first weight taken for each individual lamb just after parturition, that is after it has been cleaned and dried by the mother and is able to stand by itself. In cases when the ewes gave birth during the night or during holidays, the weight of the lamb(s) was taken within 24 hours of parturition. In this study the birth weight of the lamb was also referred to as the weight on day one, or the weight on the first day of birth.

A pan balance sensitive to the nearest hundredth of a kg was used to measure the weight of the lamb. The lamb was carefully laid down on the metal plate with as little

movement as possible. The birth weight of the lamb was recorded only after the movement of the pointer had stopped.

3.5.1.2 Monthly body weight

The dates and the body weights for each individual animals measured on the dates of weighing were recorded routinely. All the animals were weighed to the nearest hundredth of a kg. Two ropes of about one inch in diameter were used to support the animals onto the spring balance during weighing. The weights of the animals were recorded after deducting the weights of the ropes used.

Lambs from birth to about one year old were weighed fortnightly or once in fourteen days while adult animals (more than twelve months old) were weighed at about four weeks or at about 30 days interval. The present study however evaluated the growth performance of the animals by analysing the weights at day 1 (birth weight), 90, 180, 270 and 360 days old. Animals that did not have their body weights taken exactly on the dates of the age groups, their weights were interpolated using the weights prior to and after the particular age with the assumption that the body weight gain was linear during the first year of growth.

3.5.1.3 Average daily weight gain (ADG)

Daily weight gain at several age intervals were evaluated to study the growth rate of the genotypes under comparison. The age intervals included were between day 1 (birth) to day 90, day 90 to day 180, day 180 to day 270 and day 270 to day 360.

The formula used was:

$$\text{Average daily weight gain (ADG)} = \frac{\text{Final body weight (g)} - \text{Initial body weight (g)}}{\text{Age interval (days)}} \text{ (g/day)}$$

3.5.1.4 Lamb mortality

Mortality of lambs was recorded in the farm as and when it happens. Date, number and cause of mortality were recorded. However this study only considered mortalities due to natural causes and diseases. Comparison was made on lamb mortality at birth, between 2 – 90, 91 – 180, 181 – 270 and 271 – 360 days by genotypes and the year of birth.

3.5.2 Body conformation traits (BCT)

The study on the body conformation traits of the animals was carried out as an additional information to the growth performance of the genotypes. Physical measurements of each individual animal were taken at the age of 90, 180, 270 and 360 days old. Measurements taken were the animal's height at wither, body length, the heart girth and the back girth. A measuring tape and a ruler were used to take the measurements while the animal was kept standing still. The sheep's body and the position for measuring the body conformation traits are shown in Figure 3.2.

3.5.2.1 Height at wither

The height of the animal or the ventral distance was measured between the shoulder to the ground at the highest point of the withers. The animal was made to stand

straight up on a level floor or ground, while an adjusted ruler and a tape measurement were used to measure the height. Precaution has to be made, to ensure that the animal did not bend its knees or spread its legs.

3.5.2.2 Body length

The length of the animals was measured between the longest distance of the animal's body when standing that was from the outmost anterior end to the outmost posterior part of the body. Particularly, the body length should measure the distance or the extend of the animal's body, along the median line of spinous process on the first thoracic vertebra to the posterior part of the spine. During measurement the animals was ensured to stand up still.

3.5.2.3 Heart girth

The heart girth of the animals refers to the circumference of the body just behind the front legs. Measurement was made by circulating the measuring tape as close as possible to the skin of the animal, pressing down or moving the wool aside in the case of woolly sheep. The tape was positioned along the circumference, posterior to the front legs and perpendicular to the body axis.

3.5.2.4 Back girth

The method of measurement was similar to that of the heart girth. The tape measurement was positioned at the back part of the abdomen, along the circumference of the body just in front of or just anterior to the hind legs.

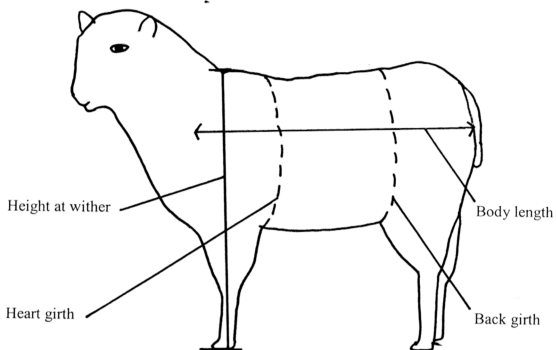


Figure 3.2 The sheep's body and the position for measuring the body conformation traits

The circumference measured should be at right angles to the axis of the body.

3.5.3 Reproductive traits

Reproductive performance of the ewes that were produced in the farm was evaluated using the data recorded for all parturition. These included data for the Cameroon, Thai Long Tail, F₁ and F₂ genotypes only. Data for the backcrosses (BC₁ and BC₂) were not included because this study focussed mainly on the filial generations of the hair types. Detail analysis on the reproductive performance of the genotypes involved was also not included as the main study was on the genetic performance of the selected genotypes. The reproductive traits that were included in this study were described below.

3.5.3.1 Age at first oestrus

Oestrus is the period during which the egg or the ovum is released from the female reproductive gland, in which the egg was formed, indicating that the female is already matured and can be mated. Females from the various genotypic groups were detected for the onset of oestrus and the subsequent oestrus cycles everyday with the help of a teaser male. Oestrus behaviour and vaginal discharge were also observed, as the young female sometimes showed silent oestrus, which required physical observation, prior to confirmation by introducing the teaser males. Age, size of the animal, body weight development and a follow up for the detection of the next oestrus cycle, were some of the factors that were considered in the determination of the date and the age when the female had the first oestrus.

3.5.3.2 Age at first successful mating

The age at first successful mating was identified after the ewes were confirmed to be pregnant. That what usually noted after the mated ewes did not come to oestrus after two breeding cycles and from the monthly weight increment. Sometimes, due to silent oestrus, confirmation was also based on the physical changes such as an increase in the size of the stomach and the udder. The date and the age at first successful mating was referred back to the latest date when the ewes were mated. Similar data collection was applied during the next mating.

3.5.3.3 Age at first and second parturition

The age of the ewes at the first and second parturition in days was calculated by referring to their date of birth. Calculation was done manually to all the ewes studied.

3.5.3.4 The first and the second gestation periods

Gestation period is the period between conception until the day of parturition and usually referred to as pregnancy period. The first day of conception was assumed by the latest date of when the animal was successfully mated or serviced. The expected date of parturition was then estimated using a reproductive calendar or at roughly fifty-two days of gestation period. In this study, the length of first and second gestation periods of the various genotypes was calculated based on the complete gestation period when the ewes were successfully mated to the date of parturition. Cases of abortion and still birth were not included in this study as they were rarely occurred.

3.5.3.5 The first and the second post-partum oestrus

The period between the day of parturition to the first day when the ewes were detected to come on oestrus again was recorded and referred as the post-partum oestrus. The length of the period or the interval between the first and the second post-partum oestrus was recorded in days and analysed.

3.6 Estimates of genetic and phenotypic parameters

The estimates for heritability were done by regressing the F_3 offspring data on F_2 ewe data. Genetic correlations were estimated using variance-covariance analysis of F_1 offspring data on Thai Long Tail ewe data and F_2 offspring data on F_1 ewes' data (Falconer, 1980). Phenotypic correlations of the F_1 and the F_2 between different body weight traits were also estimated.

3.7 Statistical analysis of data

Analysis was done using the SAS statistical package (1996) and the number of animals involved in the analysis was tabulated in the respective tables. The analysis however did not include regression estimates within the sexes and the type of birth because of the small data size and unequal subclass numbers of the genotypes involved. The number of lambs included corresponds to the number of their respective ewes. The data of the ewes were used more than once in cases where the ewes had more than one lambing.

Body weight data from birth to 360 days were subjected to analysis of variance using the SAS statistical package.

Mixed model I involved year of birth, genotype and sex as fixed effects, whereas type of birth and parity of birth were considered to be random effects. Relevant corrections were made in the analysis of variance (ANOVA) by regressing offspring weight on ewe weight at the time of birth, and also by regressing body weight at different periods on birth weight to get rid of pre-natal influence of ewe on birth weight and supposedly pre-weaning effect.

Mixed Model II was used for analysis of variance because of the insignificance of the three - factor interaction effects in Model I. Most of the results were then discussed based on the output from Model II.

The general statistical model for body weight at different ages was given by Model I and Model II.

The estimates of heritability, and estimates of genetic and phenotypic correlations were given by Model III and Model IV respectively.

Model I: Model for body weight at different ages

$$Y_{ijklmn} = \mu + \beta_{OD} + \beta_{OB} + Y_i + G_j + S_k + T_l + P_m + (YG)_{ij} + (YS)_{ik} + (YT)_{il} + (YP)_{im} + (GS)_{jk} + (GT)_{jl} + (GP)_{jm} + (ST)_{kl} + (SP)_{km} + (TP)_{lm} + (YGS)_{ijk} + (YGT)_{ijl} + (YGP)_{ijm} + (GST)_{jkl} + (GSP)_{jkm} + (STP)_{klm} + e_{ijklmn}$$

where

β_{OD} = regression of offspring weight on ewes weight at parturition

β_{OB} = regression of offspring weight on birth weight

Y_i, G_j, S_k, T_l, P_m = the main effects of year, genotype, sex, type of birth and parity of birth respectively

$(YG)_{ij}, (YS)_{ik}, (YT)_{il}, (YP)_{im}, (GS)_{jk}, (GT)_{jl}, (GP)_{jm}, (ST)_{kl}, (SP)_{km}$ and $(TP)_{lm}$

= are two factor interaction effects of year x genotype, year x sex, year x type of birth, year x parity of birth, genotype x sex, genotype x type of birth, genotype x parity of birth, sex x type of birth, sex x parity of birth and type of birth x parity of birth respectively.

$(YGS)_{ijk}, (YGT)_{ijl}, (YGP)_{ijm}, (GST)_{jkl}, (GSP)_{jkm}$ and $(STP)_{klm}$

= three factor interaction effects

e_{ijklmn}

= random error with zero mean and a common variance ($N \rightarrow 0, \delta^2$)

Model II

This is exactly the same as Model I minus all the three-factor interactions.

Model III : Estimates of heritability

Estimates of heritability of various traits were obtained by regressing the F_3 offspring data on F_2 ewe data. The model is given as the following

$$Y_{ij} = \mu + \beta_i + \varepsilon_{ij}$$

where

Y_{ij} = data of offspring

μ = common mean

β_i = regression coefficient of F_3 offspring data on F_2 ewe data

ε_{ij} = random error

Heritability estimate (h^2) was obtained by multiplying the 'b' estimate by 2. This is because, regression (b) of offspring's (O) weight on dam's (D) body weight is given as

$$b_{OD} = \frac{\frac{1}{2} V_A}{V_P}$$

therefore

$$h^2 = \frac{V_A}{V_P}$$

where V_A and V_P are additive genetic variance and phenotypic variance.

Model IV : Estimation of genetic correlation

Estimation of genetic correlation between two characters was computed by the cross-covariance method (Falconer, 1981) that is obtained from the product of value of X in parents and the value of Y in offspring. The cross-covariance (Cov_{XY}) usually gives half the genetic covariance of the two characters. The covariance of offspring and parents for each character was separately calculated, that is Cov_{XX} and Cov_{YY} . Covariance of a trait between ewe and progeny generation is $\frac{1}{2}V_A$, then

$$\begin{aligned} \text{Genetic correlation, } \gamma_A &= \frac{Cov_{XY}}{\sqrt{Cov_{XX} \cdot Cov_{YY}}} \\ &= \frac{\frac{1}{2} Cov_A}{\sqrt{\frac{1}{2} V_A \cdot \frac{1}{2} V_A}} \\ &= \frac{\frac{1}{2} Cov_{AXY}}{\frac{1}{2} \sqrt{Var_{AX} \cdot Var_{AY}}} \\ &= \frac{Cov_{AXY}}{\sqrt{Var_{AX} \cdot Var_{AY}}} \\ &= \gamma_A \end{aligned}$$

where V_A is the additive genetic variance.

Model V : Estimation of phenotypic correlation

Phenotypic correlations for the F_1 and the F_2 offsprings at the various body weight traits, at birth, 90-day, 180-day, 270-day and 360-day body weights were estimated using the variance and covariance formula given below. Data is confined within the generation.

Phenotypic correlation, $\gamma_{P_1P_2}$, is given by

$$\gamma_{P_1P_2} = \frac{\text{Cov}_{P_1P_2}}{\sqrt{\text{Var}_{P_1} \cdot \text{Var}_{P_2}}}$$

where Var_{P_1} and Var_{P_2} are the variances of the body weight traits.