Chapter 5

DISCUSSION

5. DISCUSSION

5.1 Growth performance

5.1.1 Birth weight

Crossbreeding between the Cameroon hair sheep and the Thai Long Tail wool sheep under intensive management had produced offsprings, which differed significantly ($P \leq 0.05$) in their birth weights. The least square means and the standard errors of the birth weights of the different genotypes studied are given in Table 4.4.

5.1.1.1 Effect of genotypes on birth weight

A few Cameroon hair sheep that were produced in the farm were short but stocky and had similar physical appearance as their imported parents. The analysis showed that the Cameroon had the lowest birth weight (2.52 ± 0.16 kg) in comparison to their Thai Long Tail, F_1, F_2, F_3, BC_1 and BC_2 counterparts. The mean birth weight was comparatively higher than the 2.05 kg birth weight of the Barbados Blackbelly hair sheep that were produced in Malaysia (Khusahry, *et. al.*, 1994). The German Cameroon that were imported for the experiment could have been subjected to higher inbreeding levels (Halbeisen, 1998) and therefore the size of their offspring remained very small due to the genetic effect, even though they were born in the Malaysian tropical climate. This is also perhaps due to phenomenon of reduction of body size in tropical climate that has been observed in Malaysia for other ruminant species as well.

The Thai Long Tail wool sheep, which were bigger than the Cameroon produced lambs that were heavier than the Cameroon. In this study the birth weight of the Thai Long Tail lambs under an intensive management system was 2.82 ± 0.04 kg. This weight was less than that reported by Hassan, *et. al.*, (1992), whereby under a semi-intensive management with grass and other type of forage being available in unlimited quantities, the Thai Long Tail had an average birth weight of 3.05 kg.

However the F_1, the crossbred lambs between the Cameroon and Thai Long Tail, with 50% Cameroon and 50% Thai Long Tail genes had an intermediate birth weight between the two parents (2.68 ± 0.04 kg). The birth weight of the F_1 was significantly ($P \leq 0.05$) higher than the Cameroon. The introduction of the Thai Long Tail gene, which carried bigger body size, might have contributed to the bigger size of their offsprings than the size of the Cameroon lambs. In the F_1 generation, the genotype was heterozygous for hair and wool alleles. The amount of wool in the F_1 lambs would have been reduced due to the dominant effect of the hair gene that was inherited from the Cameroon sires. This dominant effect is partial.

Similar and even superior growth performances of the F_1 crosses than their two parental genotypes were reported by Foote (1983) in his experiment with Rambouillet and Rambouillet x St. Croix lambs. The Dorset x Barbados Blackbelly crossbred lambs were reported to have higher birth weights than the Dorset straightbred lambs (Goode, *et. al.*, 1983), while superior pre-weaning weights were observed from the crosses between Barbados Blackbelly and St. Croix hair sheep sires to Sumatran purebred wool sheep in Indonesia (Gatenby, *et. al.*, 1997a). The superiority of F_1 crosses over both parents in the latter study is due to positive heterosis that has been described in detail in another chapter of this thesis.

Inter-se matings between the F_1 was carried out to produce the F_2 genotypes. Prior to that the F_1 parents were selected for hair type in order to produce the second filial generation with reduced wool cover. In the F_1 animals two types of hair coats were typical. One without wool at all or hairy type and the other common type was a kemp-like wool cover with a hair undercoat. Selection for the hairy parents was preferable to the ones with the kemp wool because of the expectation that the hair gene expression would be further enhanced in the F_2 crossbreds, that was to produce offsprings with no wool or with very little wool. Thus, this could explain the low birth weights (2.48 ± 0.05 kg.) in the F_2 lambs. It was not only lower than the birth weights of the F_1 lambs but also lower than the Cameroon's. If one assumes single gene difference between woolly and hairy coat, then there would be three types of alleles present in the F_1 genotypes, the dominant homozygous hair genes (HH), heterozygous hair and wool genes (Hh) and the recessive wool genes (hh). It was possible that the dominant hair gene expression was very strong at birth, therefore the least square means showed the lowest birth weight in the F_2 lambs. It could also be due to the use of parents with very little or no wool cover when the ewes and the rams were selected for the development of the second filial generation. Loss of half the heterosis of F_1 in F_2 could be another possible reason for lower body weight in F_2.

The F_3 generation which also had the combination of 50% Cameroon and 50% Thai Long Tail genes had birth weights higher than the F_2, F_1 and Cameroon lambs but still lower than the Thai Long Tail. There were more segregation and recombination effects expressed in the F_3. In this generation the hair genes had been further segregated, thus the effect of the dominant hair gene had been diluted. The lambs that were produced could have more of the wool type rather than the hair type. The increase in size could also probably be due to the presence of the dominant gene for size, which was inherited from the Thai Long Tail ewes. The variation in size could also be attributed to better adaptation to the environment, nutrition and the effect of the system of management of the animals and the farm during the study period.

The birth weights of the backcrosses, BC_1 and BC_2 were found to be higher than the F_1, F_2 and the Cameroon. Matured F_1 animals found to be significantly ($P<0.05$) bigger than the Thai Long Tail and with the desired hair types were used to produce the BC_1 and the BC_2. The genotypes were expected to have the heterozygous hair and wool genes and the recessive wool gene combinations. However, in the backcross animals most of the animals had wool cover but were not as woolly as the Thai Long Tail. This could probably be the reason for the higher birth weights in the backcrosses.

The BC_1 lambs were 0.11 kg heavier than the BC_2 lambs at birth (2.83 ± 0.08 and 2.72 ± 0.07 kg respectively). Having the F_1 and the Thai Long Tail as bigger parents, it was expected that their lambs would be bigger but the extra weight could also be due to the presence of more wool cover. Maternal effect of the Thai Long Tail on the size of BC_1 newborn lambs could probably contribute to the difference. The BC_2 lambs on the other hand had lower birth weight than the BC_1. Since the ewes were the F_1 females, the expression of the hair alleles by maternal effect probably was more dominant thus it contributed to having lambs with lesser wool cover. Studies on the wool or hair cover of the newborn lambs had been done by another researcher (Halbesien, 1998).

5.1.1.2 Effect of sex on birth weight

Table 4.5 showed that the effect of sex and the interaction effect between the genotypes and sex were significant ($P<0.05$). The males weighed 0.15 kg heavier than the females at birth. During pre-natal development the male foetus was reported to grow faster than the female. It could also be associated with the influence of sex.linked genes and the male growth hormones. The least square means showed that all the males from the various genotypes except the F_2 were heavier than the females at birth. The Thai Long Tail lambs were the heaviest male genotypes and the F_2 males were the lightest. The size of the parents could be the reason for the size of the lambs. Being the genotype with the lowest birth weight, the F_2 males' lambs remained the lightest. The different body sizes and the presence of hair or wool in the parental genotypes would also contribute to the significant different of the birth weights of the males between the genotype groups.

5.1.1.3 Effect of the type of birth on birth weight

The effect of the type of birth was found to be the most significant ($P \leq 0.001$) when compared to the other effects (Table 4.2). However the level of significance for the interaction effect with the genotypes was lower ($P \leq 0.05$). This showed that the main effect of the type of birth, single or twins was more and very prominent than the interaction effect. This comparison however included only the singles and the twins, as there were very few incidences of multiple births amongst the genotypes.

The single lambs were significantly ($P \leq 0.001$) heavier than the twins lambs. The least square means of the birth weights of the singles and the twins were 2.96 ± 0.03 kg and 2.41 ± 0.05 kg respectively. There was about 22.82% decrease in the birth weights of the twins in comparison to the single lambs. Other researchers (Wildeus, 1989; Filius, 1984; Gatenby, *et. al.*, 1997; Bradford, *et. al.*, 1983; Bunge, *et. al.*, 1995) had reported that the single lambs were usually bigger than the twins at birth.

There was a pronounced difference on the birth weights of the singles and the twins from the different genotypes. The backcrosses were found to produce the heaviest singles amongst the genotypes . The BC_2 had the heaviest singles while the Thai Long Tail had the heaviest mean birth weight for the twins (Table 4.6). The single lambs that were born from the F_1, F_3, BC_1 and BC_2 had higher birth weights than the purebreds parents, the Cameroon hair sheep and the Thai Long Tail wool sheep.

Figueiredo, *et. al.*, (1983) had also shown that the average birth weights of the single and twin lambs of American hair sheep breeds ranged from 1.84 kg to 3.36 kg.

They reported that the Santa Ines of Brazil was the only breed with an average birth weight of below 2.0 kg. They also found that crosses between wool breeds with high birth weights and hair breeds like Barbados Blackbelly, St. Croix and Pelibuey resulted in lambs with birth weights comparable to those of the superior parental breed. However, in the present study this was not found to be the case.

5.1.1.4 Effect of the parity of birth on birth weight

Parity of birth and the interaction between genotypes and parity of birth had also significant ($P<0.05$) effect on birth weights (Table 4.2). Least square analysis on the effect of parity showed that lambs of the second parity had the highest birth weight in comparison to lambs from the first and the second parity. Comparison between the genotypes also revealed that most of the second parity lambs had the highest birth weights as in the Thai Long Tail, F1 and BC_2. Nevertheless, first parity lambs as in the Cameroon, F_2 and BC_1 also had the highest birth weights. The results also showed that the third parity lambs from the F_3 genotype had the highest birth weights as well. The result showed that the difference in the birth weights was small and was between 0.02 – 0.04 kg. Although the difference was significant, the level of significance was low (($P\leq$ 0.05).

Studies done by Inyangala, *et. al.*, (2004) on 969 Dorper lambs weights, from birth to yearling and absolute growth rates between adjacent stages of growth indicated that sex was highly significant for all traits ($P<0.01$) and that male lambs performed in all cases considerably better than their female counterparts. These differences were significant (at least at $P<0.05$ level) for all the traits except for pre-weaning growth rate. They reported that season of birth has no significant influence on birth weight. It was evident that lambs born in the dry season performed better than those born in the rainy season. The best compromise would be to time lambing to occur towards the end of the dry season just preceding the rainy season. In Malaysia, seasonal effect (rainy or dry) does not have any significant effect on lamb growth. Abdul Wahid and Bolhassan (1994) also found this while working with the growth of younger goats.

Inyangala, et. al, (2004) also found that the effect of the parity of birth was confined to pre-weaning traits ($P<0.05$) only. In this experiment parity was shown to have significant source of variation for birth weight, pre-weaning growth rate and adjusted weaning weight ($P<0.01$). For as far as pre-weaning growth rate and weaning weight were concerned, the performance of the lambs improved with increase in parity.

It could not be concluded or assumed that older ewes could produce bigger lambs. Neither the first, second or the third parity lambs were the most preferable in terms of size at birth. The finding showed that the first, second or the third parity lambs could be bigger without depending on the parity of birth. Since the pregnant ewes that were involved in this study were well fed with concentrate pellets, freshly cut grass, mineral licks and water supply, there was a possibility that nutrition during the late pregnancy period affected the size of the foetus and the birth weights of the newborn lambs.

Other authors had reported that the type of litter, parity of birth as well as the age of the dam could influence the birth weights of their lambs (Taiwo, *et. al.*, 1982; Filius, 1984; Tuah and Baah, 1985; Armbruster, *et. al.*, 1991, Kabuga and Akowuah, 1991; Odubote, 1992; London, 1993, Yapi, 1993).

Comparison between the genotypes however showed that the size of the ewes could affect the size of the newborns as the mean birth weights of the bigger ewes were higher that the smaller ones. The Thai Long Tail ewes seemed to produce the heaviest lambs in comparison to lambs produced by the F_2 and the Cameroon ewes, which were comparatively smaller in size because of the presence of hair. This was mainly due to the bigger size of Thai Long Tail ewes.

5.1.2 Weaning weight (90-days weight)

5.1.2.1 Effect of genotypes on weaning weight

The overall result showed that the least square means for the weaning weights of all the genotypes was 13.58 ± 0.22 kg At 90 days of age the males were significantly heavier than the females, the lambs that were born as singles have higher weaning weight than the twins while the first parity lambs were heavier at weaning when compared to the second and the third parity lambs.

The least square analysis of variance revealed that effect of genotype on the weaning weights of the animals under study was not significant. However, genotype comparisons showed that Thai Long Tail lambs had the highest weaning weight (13.58 ± 0.22 kg) when compared to the other genotypes and was significantly different ($P \leq 0.05$) from the weaning weights of the pure Cameroon hair sheep (11.08 ± 0.79 kg), the F_2 (12.98 ± 0.26 kg), BC_2 (12.95 ± 0.39 kg), F_1 (12.89 ± 0.20 kg), BC_1 (12.86 ± 0.39 kg) and F_3 (12.52 ± 0.43 kg).

Under semi-intensive management Hassan, *et. al.*, (1992) reported that Thai Long Tail had an average 90-day weights of 15.30 kg. This was slightly higher that the weights of the Thai Long Tail in this study and could be due to the differences in parental stock, management system and nutrition available in the farm.

Earlier, Thai Long Tail lambs were shown to have higher birth weight than the Cameroon. This was assumed to be because of the maternal effect and the size of their parental genotypes. Due to the heterosis effect of the two parents and the inheritance for the bigger size of the Thai Long Tail ewes, it could be observed that the weights of their crosses were intermediate between the two. These results were revealed by the weights of their three filial generations, the F_2 (12.98 ± 0.26 kg), the F_1 (12.89 ± 0.20 kg), the F_3 (12.52 ± 0.43 kg). Similar results were also shown by the backcrosses (BC_1 and BC_2).

The weaning weights of the F_2, F_1, F_3 , BC_1 and BC_2 genotypes were lower than the Thai Long Tail but higher than the Cameroon. The weights of these crossbreds were also significantly different from both their parental genotypes. The significantly lower performance of the F_3 which have the lowest weaning weight amongst the F_1 and the F_2 may support the suggestion that the effect of maternal heterosis was partly lost with further crossing (Halbeisen, 1998). In this particular case, it was the loss from the Thai Long Tail ewes' genes to the F_1, the F_1 parental ewes to F_2 and then from the F_2 parental ewes to the F_3 offsprings.

These findings were similar to that reported by Boujenane, *et. al.*, (2003) on the on- station assessment of performance of the DS synthetic breed of sheep (50% D'man and 50% Sardi genes) and parental sheep breeds, D'man and Sardi. Results from their findings showed that DS lambs were intermediate to those of D'man and Sardi lambs for weight at birth, 30 and 90 days, whereas pre-weaning growth was higher. The DS lambs were 9.4% lighter at birth but 0.6 and 2.3% heavier at 30 and 90 days than the average of the parental D'man and Sardi breeds. The genotypes were found to differ ($P<0.01$) for weight at breeding, litter size at birth and at 90 days. Performance of DS ewes was in general intermediate to those of the parental breeds.

When compared to the backcrosses, the result showed that the weaning weight of the F_2 genotype (12.98 ± 0.26 kg) was higher than that of the BC_1 (12.86 ± 0.39 kg) and the BC_2 (12.95 ± 0.39 kg). The weaning weight of the F_1 genotype (12.89 ± 0.20 kg) was higher than the BC_1 (12.86 ± 0.39 kg) but lower than the BC_2 (12.95 ± 0.39 kg) genotype. However the differences were not significant. This effect was perhaps due to the strict selection for breeding males and females for more hair (less wool) to produce the respective genotypes. The F_1 parents were selected for size and hairiness although the heterotic effect was expressed in the F_3 generations. Again the selected F_1 males and females were used to produce the BC_1 and the BC_2. Therefore at the age of 90 days the crossbred lambs displayed almost similar weaning weight and not significantly different from each other. At this age, no distinct difference could be observed between the crossbred lambs and the purebred in terms of wool or hairy coat cover. The backcrosses, BC_1 and BC_2 had the weaning weights lower than the Thai Long Tail and significantly ($P \leq 0.05$) higher than the Cameroon.

The weaning weight of the BC_2 genotype (12.95 ± 0.39 kg) was higher than the BC_1 (12.86 ± 0.39 kg) but the difference between the weights (0.09 kg) was not significant. Backcrossing to the parental breed has not exhibited much effect to their weaning weight because it inherits the superiority of the F_1 genes and the Thai Long Tail sires and ewes.

Maternal effects were found to influence all traits, birth weight, adjusted 8-week weight, adjusted 16-week weight, weight at scanning, muscle depth and fat depth (Maniatis and Pollott, 2002), thus influencing the early growth of lambs in a small closed Suffolk flock. They found that for the weight traits, the size of the maternal genetic effect declined with increasing age of the lamb, the direct genetic and maternal environmental effects remained constant at all the ages studied. This could also explain why the crossbred lambs in this study performed well and had considerably higher weaning weights. In fact, a preliminary analysis of individual and maternal heterosis in this study had shown maternal heterosis was higher than individual heterosis in F_2, but this difference decreased in the F_3 (results not shown due to the limited data used in the analysis).

On the productive performance of Dorper sheep (hair and wool types) under extensive conditions in the north-western Karoo region of South Africa, Snyman and

Olivier (2002) had shown that there was no significant differences between hair and wool type lambs for body weight from 42 days until 12 month of age. No significant differences were observed for pre- or post-weaning growth rate between hair and wool type lambs.

In this study no significant differences were observed between the crossbreds with regard to hairiness although their degree of hairiness varies with age. The woolly Thai Long Tail lambs, beside the effect of the size of the parents, were a little bit heavier because the body of the lambs might have more wool cover when compared to the Cameroon lambs which have more hair and lighter.

In another study in Malaysia with Santa Ines hair sheep and its crosses with the Malaysian local wool sheep, Noraida, *et. al.*, (2003) reported the weaning weights (90-day weight) of the pure Santa Ines and its F_1 crossbreds as 13.83 ± 2.07 and 15.09 ± 1.50 kg respectively. While between the sexes, their weight were 15.54 ± 1.19 and 15.78 ± 1.75 kg for the males, and 12.14 ± 0.95 and 14.40 ± 0.91 kg for the purebred Santa Ines and the F_1 crossbreds respectively. This shows Santa Ines crosses had slightly higher weaning weights than Cameroon crosses in this study. However this study was done in a separate location and under a different feeding regime.

In another study in Malaysia, Khusahry, *et. al.*, (1994) reported the average weaning weights at 90 days of lambs from Malin, Dorset Horn x Malin (DM) and Uda ewes mated with Uda rams had the average as 11.97, 13.02 and 17.73 kg versus 10.92, 12.11 and 12.65 kg in lambs from Malin, DM and Virgin Island White (VIW) mated with VIW rams, 14.71, 14.09 and 11.69 for lambs of Malin, DM and Barbados Blackbelly (BB) ewes sired by BB. The 90 days weight of the lambs from purebred Malin and DM ewes averaged 9.68 and 11.38 kg respectively.

In Indonesia, Gatenby, *et. al.*, (1997a) reported the average weaning weight of the crossbred lambs from crosses between Sumatran ewes and Java Fat-tail (Indonesian

Fat-tailed) (E1), Virgin Island (Virgin Islands White) (H1) and Sumatran (S) rams or were inseminated with Barbados Blackbelly (B1) semen was 8.70 kg. The mean weaning weights for the lambs born to the Sumatran, E1, H1 and B1 were 8.5, 9.2, 11.7 and 12.1 kg respectively. Weaning weights of the males were higher than the females. All the breed groups had similar wool scores at the age of three months but the at older ages the scores were in the increasing order of Barbados Blackbelly, Virgin Island, Java Fat-Tail and Sumatran. Subandriyo, *et. al.*, (1998) also from Indonesia indicated that weaning weights among the F_1 crossbreds, F_2 crossbreds, Barbados Blackbelly x Sumatran, St. Croix x Sumatran and St. Croix sheep were significantly different after the effects for season, sex, age of dam and the type of birth (single or multiple) were adjusted. However, the crossbreds did not differ significantly from the crossbreds between the Barbados Blackbelly x Sumatran and St. Croix x Sumatran sheep.

The above results suggested that the weaning weights of the hair sheep breeds and their crossbreds with the local wool sheep were comparable within this hot tropical Asian region.

5.1.2.2 Effect of sex on weaning weight

Male lambs were superior to female lambs with respect to daily weight gain while the effects of breed and sex of lamb on the growth rate were significant and highly significant, respectively (Macit, *et. al.*, 2002). The superiority of the males over the males had been attributed to hormonal differences between sexes and their resultant effects on growth (Bell, *et. al.*, 1983). Consistent superiority of male lambs had been widely reported by other authors (Dass and Acharya, 1970; Fitzhugh and Bradford, 1983).

The results from this study was also in accordance to the above finding and reports from most of the authors on breeding experiments. It was shown from the analysis that the males were heavier than the females at weaning age by 1.21 kg. The effect of sex was significantly high ($P \leq 0.01$) on the weaning weights of the genotypes but the interaction effect between the genotype and sex was not significant.

The males from all the genotypes were 10.01% heavier than the females at 90 days of age. The least square means in Table 4.12 showed that Thai Long Tail males and females were the heaviest at weaning (14.26 ± 0.29 kg and 12.89 ± 0.32 kg respectively) while the Cameroon males and females were the lightest (11.12 ± 1.10 kg and 11.03 ± 1.10 kg respectively). This significant difference was due to the genetic inheritance form the small size of the Cameroon and bigger size from the Thai Long parental purebreds.

Under semi-intensive management Hassan, *et. al.*, (1992) reported that Thai Long Tail had an average 90-day weights of 16.16 for male and 14.45 kg for female lambs. This was slightly higher that the weights of the Thai Long Tail in this study and could be due to the differences in parental stock, management and nutrition.

Thai Long Tail males were 0.26 kg, 0.61 kg, 0.62 kg, 0.95 kg ($P \leq 0.05$), 1.16 kg ($P \leq 0.05$) heavier than the BC_2, BC_1, F_1, F_2 and F_3 males while the Thai Long Tail females were 0.25 kg, 0.74 kg, 0.82 kg, 0.95 kg, 1.00 kg and 1.86 kg heavier than the F_2, F_1, BC_1, F_3, BC_2 and Cameroon females respectively.

The weaning weights of the F_1 males were higher than the F_2 and the F_3 males (13.64 ± 0.25, 13.31 ± 0.35 and 13.10 ± 0.58 kg respectively). On the other hand, the F_2 (12.64 ± 0.37 kg) females had the highest weaning weight followed by the F_1 females (12.15 ± 0.28 kg) and the F_3 females (11.94 ± 0.63 kg) the lowest. The BC_2 males were heavier than the BC_1 males while BC_2 females were lighter than the BC_1 females.

In another experiment, Inyangala, *et. al.*, (2004) studied the growth traits of Dorper lambs at Ol'Magogo from birth to yearling and concluded that the effect of sex was highly significant for all traits ($P<0.01$) except growth rates between weaning and six month and six to nine months. Male lambs performed considerably better than the females and these differences were significant (at least at $P<0.05$ level) for all the growth period except for pre-weaning growth rate.

5.1.2.3 Effect of the type of birth on weaning weight

The effect of the type of birth in this study (Table 4.9) was found to be very highly significant ($P \leq 0.001$) and the interaction effect between genotype and the type of birth was also found to be significantly high ($P \leq 0.01$) on the weights at weaning. The higher weaning weights for the single lambs were probably as a result from their higher birth weights, which could have encouraged to higher milk or feed consumption from their ewes and their surroundings, thus led to higher daily weight gain and higher weaning weights.

The single lambs from the backcross animals had the highest weaning weights when compared to the Cameroon, Thai Long Tail, F_1, F_2 and F_3. The twins from the Thai Long Tail and the F_1 genotypes had the same weaning weights (12.20 ± 0.44 and 12.20 ± 0.57 kg respectively) and were the heaviest at weaning. The BC_1 twins were the third heaviest followed by the BC_2, F_2, F_3 and Cameroon genotypes.

Many authors had reported that besides the effect of the breed groups, litter type, sex and the age of mothers could also effect the pre-weaning growth rates (Bunge, *et. al.*, 1995; Martinez, 1983; Patterson, 1983; Wildeus, 1989; Zarazua and Padilla, 1983). Thus, from the study single born lambs had superiority over twins for their weights at weaning.

5.1.2.4 Effect of the parity of birth on weaning weight

There was no significant effect of the parity of birth, and the interaction effect between genotypes and the parity of birth on the weaning weights of the genotypes. The first parity lambs were the heaviest at weaning in comparison to the second and the third parity lambs (Table 4.10). The weaning weights for the first, second and the third parity lambs were 13.95 ± 0.33, 13.45 ± 0.30 and 13.29 ± 0.48 kg respectively. The second parity Cameroon lambs were the heaviest at weaning, while for the F_1 and the F_3 genotypes; lambs from the third parity of birth were the heaviest at weaning. Amongst the first parity lambs the ranking for the highest weaning weighıs was the BC_2 (15.24 ± 1.09 kg), Thai Long Tail (15.15 ± 0.35 kg), BC_1 (14.89 ± 0.73 kg) and F_2 14.17 ± 0.35 kg). The Cameroon was the only genotype that had the heaviest lamb of the second parity. The heaviest lambs in the third parity of birth was from the F_1 (14.44 ± 0.40 kg) and lambs from the F_3 genotype were the lightest (13.98 ± 0.41 kg).

Comparison between the genotypes showed that the first parity lambs from the BC_2 genotype had the highest weaning weight (15.24 ± 1.09kg) while the first parity lambs from the Cameroon genotype had the lowest weaning weight (11.35 ± 1.71 kg). In general most of the genotypes had the heaviest lambs from the first parity of birth (Thai Long Tail, F_2, BC_1 and BC_2) followed by the third parity (F_1 and F_3) and the second parity (Cameroon).

There was no consistency in the weaning weight performance of the first, second and third parity lambs amongst the genotypes. Nevertheless in some cases the weights of the third parity or the higher parity lambs seemed to be the highest. This was probably due to the effect of the age of the ewes at parturition. Dass and Acharya, (1970) and Wilson, (1987) have indicated that young ewes tend to produce smaller lambs at birth and thus the mothering ability for the first parity lambs was not as good as the ewes in the second and third parity lambing. The performance of the lambs to weaning and their weaning weight could reflect the performance of their ewes especially on their milk production and care for the young as well as the size of the ewes at the time of parturition.

First parity ewes were still growing and thus in addition to the foetal demand they must also provide for their own growth. It is generally known that mothering ability, especially milk production, increases with parity, older ewes are larger in body and better milkers. Thus, influence of the superior maternal environment of such ewes is expected to be translated into better lamb performance up to weaning. It was therefore not surprising that post weaning growth performance was not significantly influenced by parity. The effect of parity of dam on lambs is thus imparted as maternal influence whose direct influence is limited to the nursing period (Dass and Acharya, 1970; Eltawil, *et. al.*, 1970; Wright, *et. al.*, 1975; Stobart, *et. al.*, 1986)

According to Hassan, *et. al.*, (2002) the birth weight advantage was also lost with increasing age, indicating that the milk production of the ewes was inadequate to rear large size crossbred lambs. As the lambs grew older, variation between the sexes became more prominent. He also reported that crossbred lambs were heavier than indigenous lambs at birth and at all ages. This statement might be partially true in relation to the present study but it should be pointed out that the lambs with poor milking ability of their ewes were occasionally bottle fed.

5.1.3 Post-weaning weights

The post weaning weights at the age of 180, 270 and 360 days of the Cameroon, Thai Long Tail, F_1, F_2, F_3, BC_1 and BC_2 genotypes were studied and comparative performance between the genotypes, sex, the type of birth and the parity of birth were described.

5.1.3.1 Effect of genotypes on post-weaning weights

This study showed that the effect of genotypes on the post-weaning weights at the age of 180-, 270- and 360-days for the various genotypes was not significant. No significant difference between hair and wool type Dorper sheep lambs for post-weaning body weight and growth rate from 42 days until the age of 12 months was also reported by Snyman and Olivier (2002).

The overall means for the 180, 270 and 360 days post-weaning weights of all the genotypes showed an increase in weight as the animals get older. Low post weaning weights were expected in the Cameroon genotype because of its small body size and hairiness. In contrast the backcrosses especially the BC_2 were showing post weaning weights higher than the parental Thai Long Tail.

One reason could be due to the parental genes that involved for the development of the BC_1 and BC_2. In BC_2 the F_1 females were crossed back to the Thai Long Tail male and here the bigger size inherited in the selected F_1 females combined with the bigger size of the Thai Long Tail males selected for the mating. Thus the bigger size was expressed in the BC_2 lambs. Other than that, the percentage of the wool genes has increased to 75% because the crossing was made toward the hairy parental genotype. It probably would give an opposite result if the backcrossing was done to the Cameroon. This was not done because the small number of Cameroon hair sheep available in the farm during the course of the study. It was observed that the backcrosses have developed more wool cover although much lesser than the pure Thai Long Tail. The advantage in the genes for size and more wool had resulted to higher post weaning weights for the BC_1 and the BC_2. The BC_2 have shown significant difference from the other genotypic groups and was also significantly heavier than the Thai Long Tail. The BC_1 genotype in most cases was not significantly different from the three filial generations and the Thai Long Tail but towards the age of 270 and 360 days they were heavier.

The weights of the F_1, F_2 and F_3 lambs were almost similar and not significantly different. However the F_1 clearly showed its superiority in almost all the post weaning weights studied. The effect of loss of heterosis could be the reason to explain the loss in weights in the subsequent generations. The selection done for the hairy F_2 animals as parental genotypes to produce the F_3 genotypes could have added to the lowest weaning weights of the F_3 lambs.

One interesting aspect to be noted here was that the size of the F_1, F_2 and F_3 genotypes was not very much different from the Thai Long Tail. These genotypes have indirectly showed that with less wool cover and with more of a hairy coat they have gained weight as much more as to replace the formation of unwanted wool. Thus they have more meat when compared to the woolly Thai Long Tail. This could also be observed when they were compared to the backcrosses. Since the F_1, F_2 and F_3 have 50% hair and 50% wool gene and the hair gene was partially dominant, the lambs of these genotypes were either possess no wool at all (hairy) or with only kempt type of wool or very little wool cover on their back. In this regard, it is suggested that the future studies may look into the carcass traits especially meat: bone ratio in various genotypes.

At 180, 270 and 360 days old the lambs were growing on their own and almost independent from the maternal effect. Edey (1983) had described that, at least to the weaning stage, growth of animals constitutes part of the process of reproduction of the mother and the young animals itself must then continue to grow to reach sexual maturity and reproduce. During pre-weaning growth period, the maternal influence through milk intake is important while in the post-weaning growth period the animal will exhibit its own independent capability for growth until eventually achieving its mature size.

The result from this study could suggest the use of hair sheep or its crosses for meat production as it not only reduced the amount of wool but also produced almost similar quantity of meat as Thai Long Tail, and easier to manage.

From an experiment to study the feed efficiency, growth rates and carcass evaluation of St. Croix (hair sheep), St. Croix x wool sheep, Callipyge wool x wool and wool x wool, Bunch, *et. al.*, (2004) found that feed efficiency varied from 5.20 to 6.87, with the highest efficiency in St. Croix hair sheep lambs. They came to the conclusion that the value of hair sheep is from its overall meat quality and may be able to be used in terminal cross breeding programs to compete with standard breed for market lamb production. These phenomena of feed efficiency and meat quality need to be studied in Malaysia before making a judgement about the superiority of hair sheep over wool sheep.

5.1.3.2 Effect of sex on post-weaning weights

The overall result showed that in general the post-weaning weights of the males were significantly higher than the females. The males were heavier than the females at 180-, 270- and 360-days old. In another study in India, males were heavier and had a higher weight gain than females at almost all stages of growth and the difference tended to increase with age (Mandal, *et. al.*, 2003).

The BC_2 males had the highest post weaning weights in comparison to the other male counterparts, while the Cameroon males had the lowest throughout the post weaning ages. The ranking of the post-weaning weights of the males and females from the different genotypic groups was mentioned earlier in the result.

By the age of one year old the males from the F_1 genotype should be selected for further breeding as they have the highest body weight and the potential of inheriting the 50% hair genes to produce other genotypes. Even though the F_3 males have higher weight than the F_2, selecting the F_3 for further breeding might involve further losses of heterotic effect or a decline in the partial dominance of the hair gene in the next generation. Some of the F_3 have started to produce the wool and less hair than the F_2 genotype thus the higher weight could have been contributed by the weight of the wool. Therefore the choice for further breeding to produce hairy offsprings should focus more on the use of the F_1 and F_2 males. The F_1 and F_2 females also showed high matured weight and recommendable for use as breeders. The F_2 females also showed higher body weights than the females from other genotypes at the age of 180, 270 and 360 days. Although in most cases the males and females from the BC_2 have shown higher post-weaning weights, these genotypes could not be selected for further breeding because they have developed more wool cover again as an effect of backcrossing to the woolly Thai Long Tail.

5.1.3.3 Effect of the type of birth on post-weaning weights

Almost similar results were obtained with regard to the effect of the type of birth in a study by Mandal, *et. al.*, (2003). The effect of genotype has indirectly reflected the performance of the animals either by their difference in sex or the type of birth. Males were heavier and had a higher weight gain than females at almost all stages of growth and the difference tended to increase with age. Single born lambs had a distinct advantage over those born in multiple births at all stages of growth (Mandal, *et. al.*, 2003)

As have been mentioned in the results section before, the type of birth had a very high significant ($P \leq 0.001$) effect on the post weaning weight at 180-days but the degree of significance decreased at 270-days ($P \leq 0.05$) and became not significant at the age of 360-days. This showed that as the animals gets older the effect of the type of birth declined and the animals were adjusting their phases of growth to their environment. However within genotype comparison showed that at the post-weaning ages the single born lambs were still superior and significantly heavier than the twins in terms of weight development, except of the F_1 twins at the age of 270 and 360 days which were heavier than their single counterparts.

5.1.3.4 Effect of the parity of birth on post-weaning weights

The post-weaning weights also showed inconsistency in the performance of lambs from the first, second and the third parities. The effect of the parity of birth seemed to be more prominent on the weights at birth and at 90 days where in most cases the second parity lambs were the heaviest.

Influence of the superior maternal environment of such ewes is expected to be translated into better lamb performance up to weaning only and that post-weaning growth performance was not significantly influenced by parity of birth. The effect of parity of lambs is thus imparted as maternal influence whose direct influence is limited to the nursing period (Dass and Acharya, 1970; Stobart, *et. al.*, 1986)

However, the results from this study has revealed that the Cameroon, the F_2 and the F_3 genotypes were constantly showing the superiority of the third parity lambs at the post-weaning weights observed, while the first parity lambs from the Thai Long

Tail was superior throughout the post-weaning period. At the age of 180 and 270 days the second parity lambs were the heaviest in the F_1 but at 360 days the first parity lambs overtook the weight of the second parity.

In Muzaffarnagari sheep, Mandal, *et. al.*, (2003) found that the lambs that were born in the dam's second parity were generally of heavier weight and higher daily weight gain than those born inn other parities. In comparison to this study, it could be observed that in most cases the weights of the third parity lambs were found to be generally the heaviest within the groups and as shown by three of the genotypes studied. Only the BC_1 genotype showed the heaviest weight for the second parity lambs at the age of 270 days and thus it could be concluded that the parity of birth had no significant effect on the post-weaning weights.

5.1.4 Average daily weight gain (ADG) for growth performance

Significant effect was obtained for the effect of the year of birth on the average daily gain between birth weight to 90-days weight ($P \leq 0.001$) and between the age of 90 – 180 days ($P \leq 0.001$). Due to an unequal subclass number in the data collected during the years involved in the study, the effect of the year of birth was not described in the discussion although the effect was found to be significant for the weight gain between birth to 90 days and between 90 – 180 days. This significant effect could be due to the management of the animals when the genotypes were developed during the respective periods.

The effects of interaction between the genotypes and year of birth, genotypes and sex, genotypes and the type of birth were also significant for the average daily gain between the age of 90 –180 ($P \leq 0.01$) and 180 – 270 ($P \leq 0.05$); 90 – 180 ($P \leq 0.01$) and from birth to 90 days old ($P \leq 0.01$) respectively. High significant effects of the regression of offspring weight on ewe's weight at parturition ($P \leq 0.001$) and for the regression of offspring weight on birth weight ($P \leq 0.01$) on the average daily gain from birth to 90-days. The regression effects however became non-significant for the average daily gain between 90 – 180 and between 180 –270 days old. Low significant difference was later revealed for the regression of offspring weight on ewe's weight at parturition on the average daily gain between the age of 270 – 360 days ($P \leq 0.05$). This observation could be attributed to the maternal effect whereby until the age of 90 days the lambs were kept together with their ewes, thus the daily weight gain and the growth of the lambs depended on the amount of milk supplied by their ewes as well as the mothering ability of their ewes.

5.1.4.1 Effect of genotypes on ADG

Significant effect of the genotype was observed for the birth weight of the lambs only, showing that the lambs from the various genotypes varied in size at birth. However the non-significant difference on the daily weight gain between birth to 90 days old showed that the ewes were good mothers and had good mothering ability. The ewes produced enough milk to support the growth of the lambs during the pre-weaning period, thus the genotypes are comparable to each other in term of their average daily body weight gain. However, the amount of milk given to the males and the single born lambs was significantly different between the respective genotypes. As the males and the singles were bigger at birth the amount of milk intake would therefore be significantly higher than their females and twins counterparts. Thus the males and the singles were found to gain significantly more than the females and the twins until weaning. The significant difference was reflected by the effect of sex, the type of birth and the interaction effect between genotype and the type of birth.

A majority of authors had also reported that besides the effect of the breed group, sex, litter type and the age of dam at parturition could affect the pre-weaning growth rates of the offsprings (Patterson, 1983; Zarazua and Padilla, 1983; Martinez, 1983; Wildeus, 1989; Bunge, *et. al.*, 1995).

The effect of genotype in the present study was not significant for all the average daily weight gain between birth to 90, 90 – 180, 180 – 270, 270 – 360 and birth to 360 days. However the results showed that there were some significant effects within the genotypic group. The difference in daily gain was higher between lambs that were born from a bigger genotype and the age and weight of the ewes at parturition could contribute to the growth performance of the lambs up to weaning.

The genotypes in general showed that the daily weight gain decreased as the lambs get older except in the Cameroon, the F_1 and the F_3 between the age of 270 – 360 days. This could probably because of the increased in weight due to the meat production in the 100% and 50% hair sheep breed when compared to the weight due to the formation of wool in the other genotypes. In most of the periods studied, the F_1, F_2 and the F_3 gained much more than the backcrosses and the pure Thai Long Tail. This could reflect that the genotypes with more hair have better feed conversion efficiency especially towards the latter age. Therefore, by the age of 360 days the hair sheep crosses were bigger than the Thai Long Tail but slightly lighter than the backcrosses (BC_1 and BC_2). Indirectly it could be deducted that since they have no and lesser wool, the weight gain would be due to the conversion of feed to meat production instead of the conversion to wool. With more wool genes in the backcrosses, this could explain why the BC_1 and the BC_2 genotypes were slightly heavier. Other than that, heterotic effect, both individual and maternal maternal effects were expressed in the F_2 and the F_3. Studies done by Bunch, *et. al.*, (2004) on St. Croix (hair sheep), St. Croix x wool sheep, Callipyge wool x wool and wool x wool showed that feeding efficiency varied from 5.20 to 6.87, with the highest efficiency in St. Croix lambs. While standardized daily live weight gain ranged from 0.34 to 0.55 kg, with the highest rate of gain in the Callipyge wool x St. Croix crossbreds lambs.

The F_1 lambs were found to gain the most during the growth period from birth to 90-days of age. When compared to the other genotypic groups the ranking from the highest to the lowest average daily gains of all the genotypes from birth to 90-days was the F_1, BC_1, Thai Long Tail, F_2, BC_2, F_3 and Cameroon genotypes respectively.

Between the ages of 90 – 180 days and 180 – 270 days the BC_2 lambs maintained the highest average daily weight gain than the other lambs. The overall average daily weight gain of the genotypes, from birth to 360 days showed that the BC_2 genotype have the highest daily weight gain in comparison to the other genotypic groups, and thus it became the heaviest genotype. The F_1, BC_1, F_2, F_3, Thai Long Tail and Cameroon followed it respectively. The overall daily weight gains of the parental genotypes, Cameroon and Thai Long Tail were significantly lower than their crossbreds. This also showed that the growth rates of the crossbreds were better than their purebred parents. In general, the F_1, F_2, BC_1 and BC_2 have almost the same average daily weight gain and Cameroon has the least. The analysis of variance table did not show any significance different between the genotypes as the numbers were less particularly in the Cameroon.

5.1.4.2 Effect of sex on ADG

The effect of sex on the average daily weight gain was found to be significant between birth to 90-days ($P \leq 0.01$) and the interaction effect between the age of 90 to 180 days ($P \leq 0.01$) was also significant. Male lambs have significantly higher daily weight gain when compared to the males and the same observation was reported by

Macit, *et. al.*, (2003) in Awassi, Morkaraman and Tushin lambs, weaned at 2.5 months of age, fed with a concentrate mixture and allowed to graze for 70 days.

The results showed that females had higher average daily gain between the ages of 90 – 180 days and slightly higher between 0 – 90 days. Although the females had lower birth weights than the males, they began to gain weight by the milk supplied by their ewes. This could probably reflect that the ewes had good mothering and milking ability so as to enable lambs with lower birth weight to grow faster and became at par with their males counterparts. However, the males gained more in the two subsequent periods. Other than of their bigger body size, the males could be more active and eat more than the females to balance their energy loss, resulting in higher weight gain.

The sex of the lambs had no effect on their daily weight gain as the age increased. The result revealed that after weaning the lambs could survive on the feed given and available in the farm as well as became independent from their ewes. The males did have the advantage of being bigger in size and relatively were expected to eat and gain more weight. Between the age of 90 – 180 days the males were found to have less weight than the females and this could probably be due to the fact that the females were less active and the feed consumed were converted more to meat production. On the other hands the male lambs could be more active than the females and the feed consumed was being utilised more for energy production.

5.1.4.3 Effect of the type of birth on ADG

Being bigger in size at birth the single born lambs tended to have higher weight gain than the twins during the earlier parts of their lives. But after the age of 90 days the twins gained more weight than the singles.

5.1.4.4 Effect of the parity of birth on ADG

The parity of birth has significant effect for an average daily gain between the age of 90 – 180 days only. Comparison between the parity groups showed that the first parity lambs had the highest daily gain between before weaning and between the age of 270-360 days. After weaning to the age of 270 days, lambs born at the third parity were found to gain more than the first and the second parity groups while the average daily weight gains of the lambs born at second parity were an intermediate between the two groups. Variation in the daily weight gain of the parity groups could be observed and this could probably due to some management and feeding effect. Since animals in this study were not identified by their parity groups, they were individually and independently exposed to the nutrition given and the management of the farm during their growth period.

Burke, *et. al.*, (2003) reported that from birth to weaning, daily gains were greater ($P<0.01$) for Dorper x St. Croix (DS), Katahdin (KA) and St. Croix (SC) purebred hair sheep lambs when compared to the crosses between Dorper x Romanov x St. Croix (DX) and ¾ St. Croix - ¼ Romanov (SX) lambs. However from weaning to harvest, average daily weight gain was greatest ($P<0.01$) for DS followed by DX, SC, SX and KA lambs. The DX and SX crossbred lambs showed higher weight gain than the purebreds after weaning although they had lower weight gain before weaning. Similar result was observed in the present study where the crossbreds (F_1, F_2, F_3, BC_1 and BC_2) were found to gain more than the purebred (Cameroon and Thai Long Tail) lambs.

Considering all the effects above, it could be assumed that the weaned lambs especially the crossbreds were more independant and could adapt themselves to the feed given to them. Although variation could be observed within the group comparisons, this could also probably be due to the interaction effect between the genotypes. As had been mentioned earlier the genotype of the ewes had significant effect on the birth weight of the lambs. Adaptation to the maternal effect and the environment more or less have contributed to the growth rates of the lambs, thus affecting their daily weight gain.

5.1.5 Lamb mortality

The number of lamb mortality due to natural death and diseases was very low. Out of the 24 deaths during the seven-year periods (1990 – 1997) seven mortalities were recorded on day one or on the day of birth itself. The cause of death on day one was mainly due to low birth weight of less than 2.00 kg and due to some unknown reason, probably maternal effect. Low birth weight could be probably due to the nutrition, management or probably the ewes were in stress of during pregnancy although strict management has been given to the pregnant ewes especially by keeping the ewes in individual pens with extra grass and supplementary feeding. Filius (1984) reported that season, year or geographical region could influence mortality rates especially of the post-weaning growth phase including adulthood, through differences in fodder availability and parasite influence. Litter type and parity of dam have been shown to influence birth weights and can also affect survivability. Parity can affect the post-natal survivability rate through its influence on the mother's milk production.

Results on the birth weight of the lambs showed that the F_2 lambs had the lowest birth weights amongst the other genotypes. Thus high mortality in the F_2 on day one could be due to low birth weight and the lambs were too weak to survive. Meanwhile the F_3 and BC_2 lambs, which have the average birth weight of 2.74 and 2.72 kg, respectively, mortality at day one could be due to maternal problem during pregnancy as what had been stated above.

The highest mortality was recorded in the year 1996 followed by the year 1997 and 1995. No mortality was recorded in year 1990 and 1992 because the number of animals was very small and therefore all attention was focused on all the animals especially the pregnant ewes for survivability. During the two years (1990 and 1992) no mortality was recorded but the number increased in the years that follow probably due to the higher population as well as diseases.

Seven lambs died on the day of birth, 5 during pre-weaning period, 7 between the age 91 – 180 days, 4 between the age of 181 – 270 days and only 1 between the age of 271 – 360 days. It could be observed that highest mortality was recorded just after weaning until the age of 180 days. This could be attributed to the adaptation of the lambs to grass feeding and pellets and probably due to stress after been separated from their ewes at 90 days of age. Higher mortality between 181 – 270 days could be due to the same reason together with low resistance to diseases. Therefore at the age after 270 days only one incidence of death was recorded. At this particular age the lambs were expected to be already independent and can survive on their own an adapted well to the feeding, management and the environment around them.

In this study, pre-weaning mortality from birth to weaning at three months was recorded as 20.83% which was lower than 22.50% reported by Gatenby, *et. al.*, (1997) in Sumatran sheep and its crosses with the Java Fat-tail, Virgin Island, Sumatran and Barbados Blackbelly. The percentage was very much lower than the pre-weaning mortality for Djallonke sheep bred under traditional management system in West Africa which was reported at 50% (Armbruster, *et. al.*, 1991).

There were no mortalities recorded for Cameroon and BC_1 genotypes during the 1990 – 1997 period. One of the reasons could be that Cameroon was an imported hair sheep therefore extra care was provided to retain the genotype for further breeding especially on producing the F_1 and the purebred Cameroon itself. It could also reflect that the genotype was well adapted to the humid tropical climate although it was formally imported from the temperate region of Germany. Bunge, et. al., (1993) found that the higher mortality rate of wool breed lambs and their crosses compared to hair sheep lambs was attributed to the superior adaptability of the hair sheep over the wool sheep to the tropical environment.

The BC_1 genotype could have retained the hardiness from the F_1 and the Thai Long Tail. Most lamb mortality was recorded from the F_2 (10) and the F_3 (9) genotypes. Perhaps the heterotic effect reduced the degree of hardiness from their parents as well as their resistance to diseases. When the F_1 females were backcrossed to the Thai Long Tail male it could be observed that the number of mortality in their crosses (BC_2) was low and almost similar to the parental genotype.

The higher mortality rate of wool breed lambs and their crosses compared to hair sheep lambs was attributed to the superior adaptability of the hair sheep over the wool sheep to the tropical environment (Bunge, et. al., 1993).

5.2 Body conformation traits (BCT)

5.2.1 Effect of genotypes on BCT

Throughout the growth period the Cameroon remained as the smallest genotype with the lowest measurements for body conformation traits. Although the size is small it could be observed that the differences in the body measurements were not much. At 360 days old the Cameroon weighed 24.09 kg in comparison to the range between 26.48 – 28.83 kg in the other genotypes. Being a hair type and of a small size this could imply that the Cameroon genotype has a compact body type, as the weight differences from the other genotypes, the Thai Long Tail and the crossbreds could be attributed to the presence of wool. Therefore the other genotypes had higher body weight.

This result was in accordance with the finding reported by Halbeisen (1998) who also mentioned that the Cameroon represented a more compact body type than the Thai Long Tail. She found that at 360 days the Cameroon had a weight of 22.8 kg, wither height of 55.2 cm and chest girth of 62.5 cm when compared to 24.09 kg weight, 55.39 cm wither height and 69.61 cm in heart girth obtained during this study.

The results also showed that the Thai Long Tail had bigger body conformation traits than the Cameroon but comparable to the crossbreds especially with the backcrosses. At the age of 360 days, although their body conformation traits were lower in the two filial generations, the F_1 ($P<0.05$) and F_2 ($P<0.05$) have significantly heavier body weights than the Thai Long Tail while the weights of the F_3 were heavier than the Thai Long Tail but not significantly different. Their differences in body conformation traits at the age of 360 days were all significant except for the body length of the F_2 genotype. This showed that the crossbreeds with 50% hair and 50% wool genes have more meat and more compact body types when compared to the Thai Long Tail. The F_1, F_2 and the F_3 lambs used in this study mostly have hairy coat while very few have developed the kempt type of wool or patches of wool on their back. On the other hand, most of the backcross animals have less wool than the Thai Long Tail but they were heavier and in most cases their differences in the body conformation traits were mostly comparable and not significantly different ($P>0.05$). This could also be implied due to a more compact body size when compared to the bigger and woolly Thai Long Tail.

Under extensive conditions in the north-western Karoo region of South Africa, Snyman and Olivier (2002) found no significant differences between hair and wool type lambs for body weight from 42 days until 12 months of age. Their analysis of body conformation tends to suggest that the hair type lambs were blockier with shorter legs, compared to the leggier appearance of the wool type lambs. This was evident from the longer carcass length (108.5 vs. 107.2 cm) and hind leg length of wool type lambs compared to hair type lambs. They concluded that the economically important growth traits were similar between the hair and wool types of Dorper sheep. Differences that occurred in some conformation and carcass traits would not effect the economic realisation from the different types.

5.2.2 Effect of sex on BCT

In this study, the males were generally taller than the females for height at wither at the age of 90, 180, 270 and 360 days but on the other hand, the females have longer body length and bigger heart girth at all the age groups studied. Except at the age of 90 days, the females were also found to have bigger back girth than the males.

Ngere, (1973) did not find any differences between ewes and rams with regard to their body measurements in Djallonke sheep in Ghana whereby individual differences on their height at wither were attributed to the length of their legs. Similarly Dettmers (1983) suggested that adults rams and ewes differ with regard to their chest girth but the difference was not shown in growing animals.

This study however showed the superiority of the males over the females in terms of wither height only and the females showed their superiority with body length, heart girth and back girth. Perhaps the genes for body size were more expressed in the females than the males although the males were generally heavier than the females. This could also imply that the males have more compact body type than the females. Studies could be conducted to see whether there are some sex-linked genes on these traits.

The least square means showed that the measurements of the body conformation traits were proportional to the increase in age, which meant that as the animals got older there was a gradual increase in their height, body length, heart girth and back girth. The back girth was found to be bigger than the heart girth for both the males and the females in all the age groups.

The interaction effect although not significant by the least square analysis of variance showed that the males in all the genotypic groups were generally taller than the females throughout their growth period.

The Thai Long Tail males were the tallest at 90 days of age but Cameroon males became the tallest at 180 days. At 270 and 360 days the BC_2 males became the tallest animals amongst the sexes except in the BC_2 where females at 360 days old were taller than the males.

The BC_2, Thai Long Tail, BC_2 females were the tallest female genotypes at the age of 90, 180, 270 and 360. The least square means showed that the BC_2 females were the tallest at the age of 360 days and were also 1.23 cm taller than the tallest males, the BC_2.

The Cameroon females remained as the shortest females in comparison to the other genotypic groups. However, they were longer in body length and had bigger heart girth than their male counterpart at the age of 90 days, bigger heart girth and back girth at 180 days and had longer body length again at the age of 360 days.

In general the back girth measurements for all the genotypes were bigger than the heart girth. It could also be observed that the heart girth and the back girth measurements of the females genotypes from the various genotypic groups were generally bigger than the males.

5.2.3 Effect of the type of birth on BCT

In this study, the type of birth of the lambs did not have any significant effect on the body conformation traits and it could be observed that the difference in the body measurements for height at wither, body length, heart girth and back girth between the single and twin born lambs were insignificantly small.

Generally, the single born lambs were slightly taller than the twins at the age at 180 days and 270 days. However, at 360 days the twins overtook the single born lambs for their height at wither. At earlier age the males could be observed to have slightly higher measurements than the females but toward the latter age the females were taller, longer and have bigger heart girth and back girth than the single born lambs. The differences however were very small and not significant.

The non significant effect of the type of birth on body conformation traits was also reported by Ngere and Aboagye (1981) in West African Dwarf, while Atta and Khidir, (2004) found non significant effect of the type of birth on the body measurements of Nilotic sheep.

However, when Tabbaa, (2003) evaluated some factors affecting different body and fat-tail dimensions of Awassi ewes in Jordan, immediately after lambing, he discovered that the type of lambing did have an effect both on hip width and heart girth. Significant interaction between sex of lamb and type of lambing was found on hip width and shoulder height and hip height in their study, but the present work by the author did not measure those two characters. Month of lambing in Tabbaa's study showed significant influence on hip width, shoulder and hip heights and heart girth but was slightly affected the length of the tail. The coefficient of determinations had small values suggesting that other factors unaccounted for in the statistical model were responsible for the variation in these dimensions.

5.3 Reproductive traits

Reproductive traits studied in this research involved the traits that are of practical use to the animal breeders. This is also limited to females as another thesis has been written earlier on male reproductive traits from the same breeding programme.

Results of studies on the various reproductive traits of the Cameroon, Thai Long Tail, F_1 and F_2 genotypes were represented in section 4 and the least square analysis of variance showed a very high significant difference ($P \leq 0.001$) on the effect of genotypes on the age at first oestrus, age at first successful mating and age at first parturition. No significant difference was obtained for the effects of genotype, the type of birth, parity of birth, the interaction of genotype and the type of birth as well as the interaction between genotype and the parity of birth for the other reproductive characteristics.

Since there were no twins in the Cameroon, the following discussion will only involve the single born Cameroon females, Thai Long Tail, F_1 and F_2 geneotypes with respect to their type of birth and parity of birth.

5.3.1 Effect of genotypes on reproductive traits

Cameroon females were found to reach their first oestrus the earliest (241.06 ± 40.79 days) amongst the genotypes while the Thai Long Tail the latest (400.77 ± 14.97 days). Their crossbreds (F_1 and F_2) however had their first oestrus at an age intermediate of the two parents (320.09 ± 12.98 days and 322.46 ± 16.19 days). The effect of genotype was found to be significant.

The age of puberty for Cameroon was between the range of five and ten months as been reported for Pelibuey hair sheep in Mexico (Reyna, *et. al.*, 1991) but later than the West African Dwarf hair sheep females in the Federal Republic of Germany which reached their puberty between the age of 7 - 11 months old (Banze-Ngoy, 1985) and Santa Ines of Brazil at 7.3 months (Figueiredo, et. al, 1983). The Barbados Blackbelly in California and Djallonke hair sheep of West Africa were reported to have their age of puberty between the age of 4.5 to 5 months (Levine and Spurlock, 1983) and between 4 - 9 months (Armbruster, et. al., 1991) respectively, which were very much earlier than that of the Cameroon hair sheep that were bred in Malaysia.

Age of puberty depended mainly on body weight and season of birth (Reyna, et. al., 1991) while Banze-Ngoy (1985) presumed that the late maturity is due to aseasonality in oestrus and the climate in which the sheep were subjected to. As in this case the humid tropical climate could have influenced the Cameroon to reach its puberty earlier.

The Cameroon genotype was found to be the youngest to be successfully mated for the first parturition followed by the F_2, F_1 and the Thai Long Tail. Although the F_1 genotype was earlier found to have reached the age at first oestrus earlier than the F_2, the F_2 females were successfully mated on an average of thirteen days earlier than the F_1. The Thai Long Tail females were mated successfully at the oldest age when compared to the other genotypes.

The average age for all the females from the various genotypes at the first and the second parturition was 521.47 ± 0.76 days and 854.24 ± 0.57 days respectively. The Cameroon genotype had its first lambing at the youngest age (395.28 ± 46.09 days), and coincided with its youngest age at first oestrus and the age at first successful mating. The purebred Thai Long Tail lambed at the oldest age while the F_1 and the F_2 had their first lambs at the intermediate age between their parental genotype. The Cameroon hair sheep matured and successfully mated at the youngest age amongst the genotypes especially when compared to the Thai Long Tail wool sheep. This was in agreement with the description made by Fitzhugh and Bradford (1983) whereby under tropical condition the hair sheep were early maturing and lambed at younger age when compared to the wool sheep.

At the second parturition the Cameroon genotype was found to have its second lambing at the eldest age in comparison to the F_1, F_2 and Thai Long Tail. One of the possible reasons would be that the Cameroon had the longest days for the first post-partum oestrus than the other genotypes and their breeding period was not consistent. Thus the second parturition was very much later than the other genotypes.

The F_1 genotype had its first and second parturition at an earlier age than the F_2 but the differences as per least square means were only at the average of 3.61 days and 16.54 days at the first and second parturition respectively. The differences were not significant.

Age at first lambing had been studied earlier by various researchers, as well aas in this study. Galina, et. al., 1996 reported that for Pelibuey and Blackbelly hair sheep ewes studied under tropical management systems in Mexico, they had the average age at first lambing at 465 days (15.25 months). The age at first lambing for Djallonke hair sheep in Ghana was reported at twelve months old under traditional management system and 15 – 16 months under controlled breeding in improved management (Armbruster, et. al., 1991). The Sumatran, Java fat-tail (Indonesian Fat-tailed) x Sumatran (E1), Virgin Island (Virgin Island White) x Sumatran (H1) and Barbados Blackbelly x Sumatran (B1) ewes mated to the same breed type were reported to have the average age at first and second lambing as 516 and 733 days respectively (Gatenby, et. al., 1997). Later in 2002, Doloksaribu, and his co-workers, reported that the young Sumatran (S); Virgin Island x Sumatran (HC) and Barbados Blackbelly x Sumatran (BC) ewes in the humid lowland tropics of North Sumatra had the average age for the first and the second lambings, 465 and 694 days respectively, while the mean interval between the first and the second lambings was 231 days (Doloksaribu, *et. al.*, 2000).

The Cameroon hair sheep had its first lambing (about 13 months) at the age younger than the Pelibuey, Blackbelly and Djallonke hair sheep females that have been reported in the preceeding paragraph.

Variability in the lambing rate and the lambing interval observed in the above studies could be influenced by genetic and environmental factors respectively (Bradford and Fitzhugh, 1983).

The least square means of the first and second gestation period for the genotypes studied revealed the length of the first gestation as 148.71 ± 0.76 days and that of the second was 149.21 ± 0.70 days. The gestation period for the four genotypes studied, shown by the least square means ranged between 148.54 – 151.42 days for the first, and 148.30 – 150.66 days for the second gestation period respectively. Differences between the gestation period were very small and their gestation periods were almost the same.

The West African Dwarf hair sheep females in the Federal Republic of Germany was reported to have a gestation length of between 147.0 – 154.3 days (Banze-Ngoy, 1985) while the Pelibuey hair sheep in Mexico had its gestation length within the ranges reported for wool sheep breeds (148-154 days) (Reyna, *et. al.*, 1991).

In the first and the second gestation period, the Cameroon showed the longest gestation periods but only slightly longer when compared to the Thai Long Tail, F_1 and F_2 genotypes. In both comparison the F_2 genotype was shown to have the shortest gestation period, with the average of 148.54 ± 0.43 days and 148.30 ± 0.71 days for the first and the second pregnancy respectively.

The average length of the first and the second post-partum oestrus for all the genotypes were 128.60 ± 0.85 and 119.54 ± 0.75 days after parturition respectively. The length of the second post-partum oestrus was found to be shorter than the first, and in this case the length of the second post-partum oestrus was on the average of nine (9) days shorter than the first.

Lambing intervals between the first and second lambings were reported to be longer than between subsequent lambings (Kabuga and Akowuah, 1991; London, 1993) thus this was in agreement with this finding whereby the overall first lambing interval was longer than the second lambing interval.

The Thai Long Tail had the shortest first and second post-partum oestrus when compared to the other genotypes followed by the F_2, F_1 and Cameroon. Although the Cameroon had its first oestrus the earliest amongst the genotypes, the Cameroon was also found to have the longest first and second post-partum oestrus. The second post-partum oestrus for the Cameroon was 41.62 days shorter than the first.

The first and the second post-partum for the F_1 and the F_2 genotypes were intermediates of their parental genotypes, the Cameroon and the Thai Long Tail. The F_1 genotype had the second post-partum oestrus oestrus shorter than the first while the F_2 had the second post-partum oestrus longer than the first. Coincidentally, the F_1 followed the trend showed by the Cameroon while the F_2 followed that of the Thai Long Tail.

Findings by Galina, et. al., (1996) revealed that under tropical management systems in Mexico, the Pelibuey and Blackbelly hair sheep ewes had the average first lambing intervals for the years 1988 to 1994 as 265, 227, 238, 225, 252, 230 and 258 days, with an overall average of 242 days. They found that lambing interval was significantly affected by lambing season and the interval was longer for ewes lambing during autumn, winter and spring when compared to the ewes lambing in summer. The lambing interval increased significantly ($P<0.05$) as the lactation length increased from 60 to 120 days. Lambing interval and fertility was also found to be significantly correlated with rainfall, but not with temperature and photoperiod.

The mean interval between the first and the second lambings was 231 days for young Sumatran (S); Virgin Island x Sumatran (HC) and Barbados Blackbelly x Sumatran (BC) ewes in the humid lowland tropics of North Sumatra (Doloksaribu, *et. al.*, 2000). No significant effects were found for the type of breed on the age at lambing and lambing interval (Gatenby, *et. al.*, 1997).

5.3.2 Effect of the type of birth on reproductive traits

The single born females were found to have their first oestrus earlier than the twin born females but their age difference were not significant. Thai Long Tail and the F_1 singles matured earlier than the twins but the twins from the F_2 genotypes were found to mature faster than their single- born counterparts. The age at the first oestrus for the F_2 twins was the earliest amongst the twin genotypes and the second earliest after the single born Cameroon. In descending order the earliest age at the first oestrus for the single females were from the Cameroon, F_1, F_2 and Thai Long Tail while for the twins were the F_2, F_1 and the Thai Long Tail respectively.

Generally, the twins were mated successfully earlier than the singles although the singles reached their first oestrus earlier than the twins. The Cameroon singles were successfully mated earlier than the other single-born females as well as between all the groups compared followed by the F_2, F_1 and Thai Long Tail. On the other hand the twin-born F_2 genotype were the first to be successfully mated followed by the F_1 and the Thai Long Tail. Only the Thai Long Tail showed that the single born females were successfully mated earlier than the single born while other genotypes were shoeing the reverse. The F_1 and the F_2 twins were shown to be successfully mated earlier than the single born females but the differences were not significant.

The twins had the first and the second lambing earlier than the singles. All the genotypes that were born as singles were found to have their first and second parturition 2.62 days and 38.26 days later than the twins.

The Cameroon females had the longest days to have their first post partum oestrus when compared to the other single-born Thai Long Tail, F_2 and F_1 females respectively. The age at first parturition was the earliest for the F_2, followed by the F_1 and Thai Long Tail twins while the age at second parturition for the F_1 twins was the earliest in comparison to that of the F_2 and Thai Long Tail twins.

In general, it could be observed from the result that for the Thai Long Tail genotype, the single born females had their first and second parturition earlier than the twins while in the F_1 and the F_2 genotypes, the age for the first and second parturition for the twins were younger than the singles.

The single–born females and the twin born females had almost similar gestation periods. The first and second gestation period of the singles was 0.92 and 0.15 days shorter than their twin's counterparts. The first gestation period was shorter 0.65 days than that of the second gestation for the singles but 0.12 longer days for the twins. The average gestation period for both the single and the twins was 149.62 days and the effect of the type of birth on the first and second gestation period was not significant.

The single-born Cameroon had the longest length of pregnancy (151.42 ± 0.87 days) in the first gestation while the F_2 twins had the shortest (147.86 ± 0.79 days). Amongst the twin-born females, the F_1 twins had the longest first gestation period (149.90 ± 0.61 days) and the F_2 twins had the shortest (147.86 ± 0.79 days).

During the second pregnancy, the gestation period for the Thai Long Tail twins showed the longest, which was just 0.09 days more than the Cameroon singles, while the shortest gestation period was observed in the F_2 twins. The single born Cameroon and the Thai Long Tail twins showed the longest gestation period for the singles and the twins in the second gestation period.

The overall result revealed that the average gestation period for the single and twin females from all the genotypes during the first gestation were 149.16 ± 0.45 and 149.15 ± 0.65 days and, for the second gestation were 149.22 ± 0.57 and 148.99 ± 0.91 days respectively.

The length of the first and the second parturition the post-partum oestrus of the single-born females were shorter than that of the twin born females. The length of the first post-partum oestrus for the singles was found to be shorter than the second post-partum while that of the twins was almost similar. These differences were not significant.

The single-born Cameroon had the longest time to first-partum oestrus while the F_2 singles had the longest second post-partum oestrus among the singles and the twins. The second post-partum of the F_2 single females were only on the average of 2.21 days longer than the Cameroon singles. Amongst the twin born genotypes, the F_1 and the Thai Long Tail twins had the shortest first and the second post-partum oestrus respectively. In the second post-partum, the twins from all the genotypic groups had their post-partum oestrus earlier than their single born counterparts.

It could also be observed in the single born genotypes, that the Cameroon hair sheep had the longest first and second post-partum oestrus while the Thai Long Tail, a wool sheep genotype had the shortest. The F_1 and the F_2 crossbreds had the length of both the oestrus as an intermediate between the two parental genotypes. The trend was almost the same after the second parturition except that the F_2 singles had slightly longer oestrus than the Cameroon. In the second post-partum, the F_1 and the F_2 twins had their oestrus longer than their Thai Long Tail parental genotype.

5.3.3 Effect of the parity of birth on reproductive traits

No significant difference was found for the effect of the parity of birth on the age at first oestrus and other reproductive traits.

At the age for first oestrus, generally the second parity females were found to reach their age at first oestrus as the earliest followed by the females of parity four, parity one and parity three. Females from the parity 2 of the Cameroon genotype reached their age at first oestrus at the youngest age while females of parity 3 from the Thai Long Tail reached their age at first oestrus at the latest age. This followed the effect of genotype but was not significant.

Comparison between the parity groups showed that parity 1 females from the Cameroon genotype matured fastest when compared to parity 1 females from the F_1, F_2 and Thai Long Tail. Parity 2 females from the Cameroon genotype also matured the earliest among the parity 2 females followed by the F_1, F_2 and Thai Long Tail. Parity 3 females from the F_2 genotype matured at the earliest age when compared to the parity 3 females from the F_1 and Thai Long Tail genotypes. Parity 4 females from the F_1 had their age at first oestrus faster than the parity 4 females from the Thai Long Tail parents.

In general, it was revealed that the purebred females from the first and second parity group of the purebred Cameroon hair sheep matured earlier than the purebred Thai Long Tail wool sheep. The crossbred females of parity 1 to parity 4 however matured later than the purebred Cameroon (parity 1 and parity 2) but earlier than their Thai Long Tail wool sheep ewes.

The parity four females were mated succesfully at the youngest age when compared to females of parity one, parity three and parity two. It could be observed that with subsequent parities the females were able to reproduce faster. In contrast to the age at first oestrus, the parity two females were the earliest to mature but the last group to be successfully mated.

There was some inconsistencies in the effect of parity on the age of successful mating. However it could be observed that parity one females from the Cameroon genotype were found to produce offspring at the youngest age of all followed by the parity two females from the same genotype.

For the age at first and second parturition, females from parity 2 had their first parturition earlier than the other parity groups while females of parity 4 had the second parturition earlier than the parity 1, parity 2 and parity 3. Parity 3 females from all the genotypes were found to be the oldest at the first and second parturition. This could be related to earlier finding that the third parity females for the various genotypes had their first oestrus at the oldest age than females of parity 1, parity 2 and parity 4. Parity 1 females could be observed to have had their age at first and second parturition latter than the parity 2 and parity 4 females. Thus, females born at parity 2 and parity 4 were the youngest at the first and the second parturition. On the other hand parity 3 females were the oldest at the first and second parturition and parity 1 females were the second oldest by age at the first and second parturition respectively. All the differences were not significant except those in the second parturition.

Parity 2 females from the Cameroon were the youngest (389.22 ± 49.36 days) at the first parturition and the F_1 had the earliest at the second parturition than parity 2 females from the other genotypes. For Cameroon, there is almost no difference between parity 1 and parity 2 females. Both parity 1 and parity 2 females from the Cameroon genotype had their age at first parturition faster than parity 1 to parity 4 from the other genotypic groups. However the Cameroon was found to take a longer period to have the second parturition in comparison to the other parity groups within and between the genotypes. This was obviously due to the fact that the Cameroon took the longest time to get the first post-partum oestrus and get pregnant than the other genotypes. Thus the result had shown that the Cameroon had the second parturition later than the others.

The least square means of the first and second gestation periods for all the parity groups was on the average of 149.63 days. The first gestation periods for the parity 1 and parity 2 were only 0.39 days and 0.17 days longer than the second gestation. On the other hand the first gestation periods for the parity 3 and parity 4 females were 0.34 days and 1.36 days shorter than the second gestation period. The third parity females had the shortest gestation period in the first pregnancy while the first parity females had the shortest gestation period in the second pregnancy.

The second post partum oestrus for the parity 1, parity 2 and parity 3 females were shorter than the first one. On the other hand, parity 4 females had the longest time to have the second post-partum oestrus. For the first and the second parturition, parity 3 females had the shortest first and second post-partum oestrus in comparison to that of parity 1, parity 2 and parity 4 females. The first post-partum oestrus of the parity 1, parity 2 and parity 3 females were 6.43, 9.10 and 13.56 days longer than their second post-partum oestrus. On the other hand, the parity 4 females had the second post-partum 5.47 days longer than the first. Parity 4 females were also found to have the longest first and second post-partum oestrus.

Parity 1 females from the Cameroon genotype had longest interval to have the first and second post-partum oestrus. On the other hand parity 1 females from the Thai Long Tail had the shortest interval. The length of the first and the second post-partum oestrus for the parity 1 females of the F_1 and the F_2 crossbreds were the intermediates of that of the Cameroon and the Thai Long Tail.

The length of the first and the second post-partum oestrus of the Cameroon decreased from parity 1 to parity 2 while that of the Thai Long Tail, increased from parity 1 to parity 4 in the first post-partum and from parity 1 to parity 3 in the second post-partum. No specific trend could be observed in the F_1 and the F_2 genotypes.

Parity 1 and parity 2 females from the Cameroon genotype showed the longest gestation period in the first (152.05 ± 1.60 days) and the second (151.16 ± 1.20 days) gestation period respectively, while the shortest gestation period was shown by the parity 3 (147.02 ± 1.60 days) and parity 2 (146.05 ± 1.70 days) females of the F_2 genotype.

According to Armbruster, *et. al.*, (1991), Kabuga and Akowuah (1991) and Filius (1984), the number of parity of the ewes with respect to age of ewe at lambing had a significant influence on the lambing interval while London (1993) and Filius (1984) found an increase in the lambing interval with the number of parities being greater than 6.

5.4 Estimates of genetic and phenotypic parameters

5.4.1 Heritability estimates

The results in Table 4.53 showed that direct additive estimates of heritability were 0.68 ± 0.48, 0.34 ± 0.64, 0.90 ± 0.82 and 0.26 ± 0.62 for birth weight, 90-day body weight, 180-day body weight and 270-day body weight. The estimates are moderate to high indicating the presence of substantial additive genetic variance, which can be exploited for selection towards improvement of body weight traits.

The estimates fluctuate from 0 day to 270-days, which may be due to various reasons; small sample size and perhaps varying feeding regime. In the University of Malaya's farm, grass supply increased during rainy season and it decreased during dry season when animals to a large extent become dependant on concentrate supply. The concentrate mixture also varied because of non-availability of brewer's waste at certain periods. The proximate composition of the concentrate varied according to the availability of the ingredients.

Heritability estimates obtained from this study were surprisingly high, at least for one trait, 180-day body weight. In most other hair sheep studies on heritability, the estimates were found to be much lower.

Kiriro (2001) while working with Dorper hair sheep in South Africa obtained much lower estimates of heritability (0.14 ± 0.06 for birth weight and 0.08 ± 0.05 for weaning weight). Similar estimates were obtained from other studies in wool sheep (Suvindra and Tamar, 1982; Johor and and Norton, 1977), in Corriedale sheep in India, and also in Suffolk and Targhee sheep in India respectively. However, in Suffolk lambs in Japan, Yamaki (1994) showed that the estimates of heritability in body weight trait could be as high as revealed in the present study. Yamaki's estimate ranged from 0.13 ± 0.06 to 0.66 ± 0.22 in birth weight, weaning weight and 14-month weight. In Yamaki's estimates, he obtained an increasing trend in the estimates of heritability with increasing age. No such trend was observed in this study.

5.4.2 Estimates of genetic and phenotypic correlations

The genetic correlation obtained through the regression of the F_1 offspring data on the Thai Long Tail (TLT) data and the F_2 offspring data on the F_1 parent data (Falconer, 1980) were much lower than the phenotypic correlations between traits: 0-day and 90-day weight, 0-day and 180-day weight, 0-day and 270-day weight, 90-day and 180-day weight, 90-day and 270-day weight, and 180-day and 270-day weight.

Again, when the F_1 – TLT estimate of genetic correlation was compared with the F_2 – F_1 estimates of genetic correlation, the latter estimates were found to be much higher than the former estimates. In many studies with animals, the regression of F_2 data on F_1 data has been preferred and the estimates of genetic correlation were reported to be higher.

Phenotypic correlations between different body weight traits were found to be not consistent across generations (Table 4.55). The F_2 estimates were in general higher than the F_1 estimates. All traits were positively correlated at a moderate to higher level. Values ranged between 0.23 to 0.92 in F_1 and between 0.51 to 0.96 in F_2. The standard errors of phenotypic correlations ranged from 0.08 to 0.96, showing considerable differences in the limits of estimation of heritability.

In general, the genetic correlation will be much lower than phenotypic correlation. This trend was also observed in this study whereby the values for genetic correlations between traits ranged between –0.07 to 0.25 and 0.06 to 0.38 for the F_1 – TLT and the F_2 – F_1 estimates respectively, while the range for the phenotypic correlations was between 0.23 to 0.92 in the F_1 and between 0.51 to 0.96 in the F_2. The range for the genetic correlation in this study was very much lower than that reported by Inyangala, *et. al.*, (2004) for Dorper lambs. They estimated the genetic correlations as between 0.15 to 0.99 while the phenotypic correlations between 0.02 to 0.98. However the range for the phenotypic correlations obtained from this study was within the range reported by Inyangala and his co-workers.

The high positive genetic correlation between the pre-weaning and the post-weaning growths showed that compensatory growth would appear to be mutual effects of genotype and phenotype, and these estimates would be useful in future as a selection strategy for sheep improvement.

The phenotypic correlation is expected to be much higher than the genetic correlation as it depends on the genetic correlation and the environmental correlation between the two traits, the heritabilities of the two traits and the common and specific environmental effects on the two traits. This is illustrated by the following diagram

(Figure 5.1) where P_1 and P_2 are two characters, and $\gamma_{P_1P_2}$ and $\gamma_{G_1G_2}$ are phenotypic and genetic correlations respectively, h_1 and h_2 are the square roots of the heritability for the two traits. E_1 and E_2 are environmental effects at different times on the two traits and e_1 and e_2 are the paths that connect E and P. $\gamma_{E_1E_2}$ is assumed to be one as the environmental correlations as the environment during the short time interval would not change very much in Malaysia.

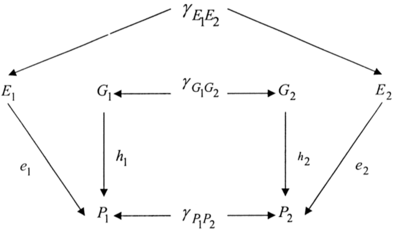

Figure 5.1 Path diagram showing the relationship between the phenotype and the genotype of two traits and the environmental effects on the two traits

Since the estimates of genetic correlation between traits in hair sheep breeds are rarely reported, further studies are required on hair sheep which are now distributed from a few tropical countries to many humid and dry tropical countries.