AN ABSTRACT OF THE THESIS OF

GLAFIRO TORRES-HERNANDEZ for the degree of DOCTOR OF PHILOSOPHY in ANIMAL SCIENCE (Breeding & Genetics) presented on 8/23/79

TITLE: MILK PRODUCTION AND PROGENY GROWTH IN CROSSBRED SHEEP

I. GENETIC AND ENVIRONMENTAL EFFECTS ON MILK PRODUCTION, MILK COMPOSITION AND MASTITIS INCIDENCE IN CROSSBRED EWES

II. RELATIONSHIPS BETWEEN EWE MILK PRODUCTION AND COMPOSITION AND PREWEANING LAMB WEIGHT GAIN

III. BIOMETRIC PROPERTIES OF LACTATIONS IN EWES RAISING SINGLE OR TWIN LAMBS

Abstract approved: Redacted for privacy

William D. Hohenboken

I. GENETIC AND ENVIRONMENTAL EFFECTS ON MILK PRODUCTION, MILK COMPOSITION AND MASTITIS INCIDENCE IN CROSSBRED EWES

Fifty-six 3- and 4-year old ewes were hand milked approximately every 2 weeks for a 15-week lactation to examine differences among eight crossbred groups in milk production, milk composition and lactation curve and to study the influence of ewe age, number of lambs suckled, stage of lactation and mastitis infection on milk production and composition. Ewes 1/2 Dorset or 1/2 Cheviot produced more milk than ewes 1/2 Finnsheep or 1/2 Romney ($P<.10$). Ewes 1/2 Dorset or 1/2 Romney had higher milk protein percent than 1/2 Finnsheep or 1/2 Cheviot ewes ($P<.01$). Suffolk crossbreds had higher milk protein percent than Columbia-type crossbreds ($P<.01$). Lactation curves were of similar shape for each crossbred group. Milk production peaked approximately 3 weeks <u>post partum</u> and then decreased to the 15th week. Ewes nursing twins produced 22% more milk than ewes nursing a single lamb. Percentages of both protein and fat increased significantly with stage of lactation. Ewes free of mastitis produced 12% and 58% more milk than ewes with one half or both halves of the udder infected, respectively. Milk from ewes free of mastitis had lower protein percent than milk from ewes with mastitis infection ($P<.01$). Cheviot crossbreds were above average, Dorset crossbreds were slightly above average and Finnsheep and Romney crossbreds were below average in incidence of mastitis. Mastitis occurred at random

with respect to stage of lactation and number of lambs suckled but not with respect to repeated observations on the same ewe. The correlation between subjective condition score and total milk production was -.25.

II. RELATIONSHIPS BETWEEN EWE MILK PRODUCTION AND COMPOSITION AND PREWEANING LAMB WEIGHT GAIN

Fifty-six 3- and 4-year-old ewes from eight crossbred groups were hand milked and their lambs weighed approximately every 2 weeks for a 15-week lactation period to study relationships of ewe milk production (MP), percentage milk protein (PMP) and percentage milk fat (PMF) to preweaning weight gain (G) of single and twin lambs. Regression coefficients of G on MP and corresponding correlations were large and significant toward the start of lactation and generally decreased as lactation progressed. For the entire lactation, regressions of G on MP were .11 kg/l ($P<.05$) and .07 kg/l ($P<.05$), while correlations between G and MP were .64 ($P<.01$) and .55 ($P<.01$) for single and twin lambs, respectively. G of single lambs was predicted most accurately from MP and PMP, while in twin lambs milk composition terms did not improve the precision in predicting G from information on MP alone. Breed of dam influenced G of twin lambs but not of single lambs significantly. Lamb sex did not significantly influence MP nor G. Regression equations to predict milk production from weight gain of single and twin lambs were also obtained. For the entire lactation the regression coefficients were 3.74 l/kg ($P<.05$) and 4.27 l/kg ($P<.05$) for single lambs and twins, with r^2 values of .41 and .30, respectively. Single lambs gained more weight during lactation than the average weight gain of one twin lamb. The total gain of twin sets, however, was much greater than gain of a single lamb.

III. BIOMETRIC PROPERTIES OF LACTATIONS IN EWES RAISING SINGLE OR TWIN LAMBS

The lactation curves of 21 single- (SR) and 28 twin-rearing (TR) ewes were fitted, and their milk production was estimated by the model $Y = ax^be^{-cx}$, developed in England for dairy cattle. In addition, persistency of lactation of SR and TR ewes was compared by five procedures

reported in the literature. Results indicated that the coefficients that characterize the shape of the lactation curve (b and c values) were of similar magnitude to those reported in dairy cattle, thus defining a curve of similar shape. Near parallelism between curves of SR and TR ewes was observed throughout lactation, with more milk production from TR ewes. The correlation was .98 ($P<.01$) between total milk production estimated by this model and that based on the sum of partial lactations, although slightly more precision was obtained from the latter method. Lactations of SR ewes had similar persistency to those of TR ewes.

MILK PRODUCTION AND PROGENY GROWTH IN CROSSBRED SHEEP

by

GLAFIRO TORRES-HERNANDEZ

A THESIS
Submitted to
Oregon State University

in partial fulfillment of
the requirements for the
degree of
DOCTOR OF PHILOSOPHY
June 1980

APPROVED:

Redacted for privacy

Associate Professor of Animal Science
in charge of major

Redacted for privacy

Head of Department of Animal Science

Redacted for privacy

Dean of Graduate School

Date thesis is presented August 23, 1979

Thesis typed by Georgette Fosque for GLAFIRO TORRES-HERNANDEZ

TO THE MEMORY OF MY FATHER

Dear Dad:

I came to Oregon State University shortly after you left us. There were very difficult moments throughout my entire Ph.D. program especially at the beginning, when I was still suffering about you very much. Today, such difficulties have been overcome with the completion of my degree.

This piece of work represents not only my efforts and those of my family. When writing, I was always inspired by you based on your constant preoccupation in life to leave your sons and daughters the most precious inheritance: a good education. I will never forget the many sacrifices in your life that you made to accomplish that objective. Therefore, you are the real owner of the diploma that I have been given today.

THANK YOU DAD! THANKS FOR SO MANY THINGS!

your son,
Glafiro

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Dr. William D. Hohenboken, his major advisor, for his guidance and patience during the preparation of this dissertation. His continuous counsel and encouragement throughout my Ph.D. program are greatly appreciated.

I thank Drs. Dave England, Walter Kennick, Lyle Calvin and Carl Schreck for serving on my graduate committee.

I thank the Mexican government for their financial support through the "CONACYT" scholarship.

I thank Georgette Fosque for her assistance in typing my dissertation.

Finally, I thank my wife Aracely, my daughters Lorena and Marissa, and my son Edgar (born in Corvallis) for their understanding, encouragement and many sacrifices during my studies at Oregon State University. I am sure we will spend more hours together from now on.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GENETIC AND ENVIRONMENTAL EFFECTS ON MILK PRODUCTION, MILK COMPOSITION AND MASTITIS INCIDENCE IN CROSSBRED EWES[1]

Glafiro Torres-Hernandez[2] and William Hohenboken[2]

[1]Technical Paper No. 4971, Oregon Agricultural Experiment Station. Contribution to North-Central Regional Project NC-111, Increased Efficiency of Lamb Production.

[2]Department of Animal Science.

SUMMARY

Fifty-six 3- and 4-year-old ewes were hand milked approximately every 2 weeks for a 15-week lactation to examine differences among eight crossbred groups in milk production, milk composition and lactation curve and to study the influence of ewe age, number of lambs suckled, stage of lactation and mastitis infection on milk production and composition. Ewes 1/2 Dorset or 1/2 Cheviot produced more milk than ewes 1/2 Finnsheep or 1/2 Romney (P<.10). Ewes 1/2 Dorset or 1/2 Romney had higher milk protein percent than 1/2 Finnsheep or 1/2 Cheviot ewes (P<.01). Suffolk crossbreds had higher milk protein percent than Columbia-type crossbreds (P<.01). Lactation curves were of similar shape for each crossbred group. Milk production peaked approximately 3 weeks _post partum_ and then decreased to the 15th week. Ewes nursing twins produced 22% more milk than ewes nursing a single lamb. Percentages of both protein and fat increased significantly with stage of lactation. Ewes free of mastitis produced 12% and 58% more milk than ewes with one half or both halves of the udder infected, respectively. Milk from ewes free of mastitis had lower protein percent than milk from ewes with mastitis infection (P<.01). Cheviot crossbreds were above average, Dorset crossbreds were slightly above average and Finnsheep and Romney crossbreds were below average in incidence of mastitis. Mastitis occurred at random with respect to stage of lactation and number of lambs suckled but not with

(Key Words: Crossbred Ewes, Milk Production, Composition, Mastitis.)

respect to repeated observations on the same ewe. The correlation between subjective condition score and total milk production was -.25.

INTRODUCTION

The influence of maternal effects on preweaning growth in livestock has been shown by many investigators. The dam's milk production is a major cause for this maternal effect, since preweaning growth is largely dependent on the amount of milk consumed (Robinson et al., 1969; Warren and Renbarger, 1963). Additional research concerning differences in milk production among sheep breeds and crosses may provide insight into causes of differences among them in lamb production at weaning.

The objectives of this study were to determine: 1) whether eight groups of crossbred ewes differed in 24-hr milk production, milk composition or shape of the lactation curve and 2) whether milk production and milk composition were influenced by age of the ewe, number of lambs suckled, stage of lactation and mastitis infection. The relationship between milk production of the ewes and preweaning growth of their lambs will be reported in a separate paper.

MATERIALS AND METHODS

Population and Management. The study was conducted at Oregon State University from February to June, 1977. The 56 3- and 4-year-old ewes included in the experiment were from crosses of North Country Cheviot, Dorset, Finnsheep and Romney rams on Suffolk and Columbia-type range ewes. They were chosen from among 182 ewes on irrigated pastures as part of a larger experiment described by Cedillo et al. (1977). All the ewes had been group mated to Hampshire rams, so all lambs were three breed crosses of 50% Hampshire inheritance. Lambing began on February 14 and extended until March 18, but all ewes in this study lambed between February 16 and February 27, 1977. Ewes and their lambs were moved to mixed grass/legume pastures when the lambs were 5 to 10 days of age, and they remained in that environment until weaning on June 7. Pasture conditions were excellent throughout the experiment, and the entire flock was rotation-grazed at a stocking density of 20 ewes and their lambs per hectare. Ewes did not have access to supplemental feed, but lambs were creep-fed until weaning. Additional management procedures for the flock are described by Klinger and Hohenboken (1978).

Once lambing began, the first seven ewes to lamb per crossbred group and to have one or two healthy lambs survive to 3 days of age were allotted to the experiment. This scheme does not adhere to statistically desirable random sampling. However, nomination of ewes within group before lambing began would have created more problems than it solved, primarily by extending the time interval over which lactation began.

Milking Procedure. The first milking took place about 1 week *post partum*; thereafter milkings were conducted approximately every 2 weeks for a 15-week period. Early in the morning on each milking day, the ewes and their lambs were separated from one another and from the remainder of the flock. Each ewe was suspended in a canvas stretcher with holes for each leg and the udder. Once suspended, she was injected in the jugular vein with 5 IU of oxytocin in physiological saline and rapidly hand milked by two milkers. When no more milk could be obtained, she was again given 5 IU of oxytocin and milked to insure as complete evacuation of the udder as possible. This milk production was not recorded. However, milk from each half of the udder was tested for mastitis using the California Mastitis Test or CMT[3], a procedure widely used in the dairy cattle industry. When a ewe reacted positively to this test, she was injected intramuscularly with 10 cc of penicillin-streptomycin and given a 2.5 g oral bolus of sulfadimethoxine per 45 kg of body weight. Ewes were then held away from their lambs for at least 3, but no more than 6 hr, after which the entire milking procedure was repeated. McCance (1959) reported that milk synthesis over an interval of 4 to 6 hr after complete evacuation of the udder was a reliable reflection of normal milk synthesis throughout the day. At this second milking, milk volume was recorded to the nearest ml, and a 25 ml-sample

[3]Dairy Research Products, Inc., Brunswick, MA 21716.

was collected and frozen for later assessment of composition. Ewes and lambs were then returned to the main flock.

Milk production rate (ml/hr) was calculated by dividing the volume obtained in the second milking by the time between completion of the two milkings. This was multiplied by 24 to estimate 24-hr milk production in ml per day.

Analytical procedures to determine percent of protein and fat from early, mid and late lactation samples utilized the Udy Protein Analyzer-Model L[4] and Banco procedures[5], respectively.

After the final milking (approximately 15 weeks *post partum*), each ewe was scored independently for body condition by four scorers using the technique of Pollott and Kilkenny (1976), and the average of the four scores was her subjective condition score.

Statistical Analysis. Dependent variables were estimated 24-hr milk production, percent protein and percent fat. Analyses were by least-squares split-plot analysis of variance. For 24-hr milk production, variation between ewes (main plot) included as discrete fixed independent variables breed of the ewe's sire, breed of the ewe's dam, sire x dam breed interaction, age of the ewe, number of lambs being suckled (two *vs* one) and the among-ewes-within-sub-groups residual, used as the denominator in the F ratio to test all main plot effects. Variation within ewes (sub plot) included as discrete fixed independent variables stages of lactation (first through eighth milking), sire x dam x stage of lactation interaction, CMT result (coded as zero, one and two for no reaction, reaction in one half of the udder and reaction in both halves of the udder, respectively) and the within-ewes residual, used as the denominator in the F ratio to test all sub plot effects. For percentages of both protein and fat, discrete fixed independent variables were as above plus crossbred group x age of the ewe interaction and crossbred group x number of lambs being suckled interaction, both included as main plot effects. These two interactions appeared in the model for percentages of protein and fat but not in the model for 24-hr milk production,

---

[4]Udy Analyzer Co., Boulder, CO 80301.
[5]Anderson Laboratories, Inc., Fort Worth, TX 76101.

because preliminary analysis indicated they were neither significant nor important for the latter variable. Tests of significance for the effects of stage of lactation, the sire breed x dam breed x stage of lactation interaction and CMT score on 24-hr milk production and percent protein were by the "conservative F ratio" procedure recommended by Gill and Hafs (1971).

Furthermore, χ^2 tests were performed to determine 1) whether crossbred groups differed in mastitis incidence, 2) whether mastitis incidence differed among stages of lactation, 3) whether number of lambs suckled influenced mastitis incidence and 4) whether mastitis occurred at random with respect to repeated observations on the same ewe. Of 433 mastitis tests, 50 or 11.5% reacted positively. Therefore, if mastitis occurred completely at random, 11.5% of the observations in each genetic or environmental subgroup should yield a positive test. This probability was used to compute expected incidences to which observed incidences were compared by χ^2 for breed groups, stages of lactation and number of lambs suckled. If mastitis occurred at random with respect to repeated samples on individual ewes, then the proportion of ewes with 0, 1, 2, ..., 8 positive tests for mastitis should agree with the expanded binomial $(.88 + .12)^8$ where .88 is the proportion of negative tests and .12 is the proportion of positive tests in the records of 51 ewes which had CMT test scores for all eight milkings.

Finally, milk production per ewe for the entire 15-week lactation was estimated as 24-hr milk production times the appropriate number of days which bracketed each milking, summed over the eight milkings. The correlation between this estimated total milk production and subjective condition score was computed on a within crossbred group basis.

RESULTS AND DISCUSSION

Genetic Effects. Split-plot analyses of variance for the three dependent variables are summarized in table 1; least-squares means for breed effects on 24-hr milk production and milk composition are presented in table 2. Estimated milk production of 1,090 ml/day (approximately 1,128 g/day) is within the range of values reported in the literature such as 970 g/day (Corbett, 1968), 1,380 g/day (Langlands, 1973), 1,476 g/day (Coombe et al., 1960), and 2,052 g/day (Gardner and Hogue, 1966). Breed of the ewe's sire influenced 24-hr milk production ($P<.10$). Dorset- and Cheviot-sired ewes produced the greatest amount of milk, Romney-sired ewes were intermediate, and Finnsheep-sired ewes were the least productive. The effect of 1/2 Columbia-type vs 1/2 Suffolk inheritance was negligible, as was the sire x dam breed interaction. Addleman et al. (1964) reported that average grams of milk produced per day for ewes nursing single and twin lambs, respectively were: Border Cheviot, 1,016 and 1,669; Dorset Horn 1,616 and 1,778; Columbia, 1,366 and 1,684; Suffolk, 1,527 and 2,287 and Willamette, 1,552 and 1,951. When twin-bearing Romney and 3/4 Cheviot crossbred ewes were compared for a 12-week lactation period (Barnicoat et al., 1956b), the average yield in both groups was 1,566 g/day. A study by Geenty and Jagusch (1974) compared milk production of Dorset, Corriedale and Romney ewes rearing twins during a 12-week lactation; average milk yields were 2,238, 1,905 and 1,607 g/day, respectively.

In the present study, lactation curves for each crossbred group were approximately the same shape, as suggested by the nonsignificance of the crossbred group x stage of lactation interaction.

A significant effect on percent of milk protein was exerted by breed of the ewe's sire, breed of the ewe's dam and the sire x dam breed interaction. Plotting of the values showed that the ranking of the four breeds of sire was consistent across both breeds of dam; therefore the interaction was not considered to be biologically important. Dorset- and Romney-sired ewes had essentially the same percent of milk protein (5.04 vs 5.06%, respectively), and these values were higher than those for Finnsheep-sired ewes (4.83%) and for Cheviot-sired ewes (4.67%). Ewes from Suffolk dams had higher percent protein in their milk (5.07%) than ewes from Columbia dams (4.73%). There were no significant differences among breeds for percent fat. Addleman et al. (1964) and Slen et al. (1963) reported no significant differences among breeds for either percent protein or percent fat. Barnicoat et al. (1956b), however, found a significantly higher percent of fat in the milk of Romney than 3/4 Cheviot crossbred ewes, while the reverse was true for percent protein.

Gardner and Hogue (1966) reported that percent fat was significantly higher for Hampshire than for Corriedale ewes. Barnicoat et al. (1949a) and Owen (1957) indicated that values for fat and total solids were generally more variable than those for solids-non-fat (where protein is included). Our data support this conclusion; residual standard deviations for protein and fat, respectively, were .30 and .90%.

The nonsignificance of the crossbred group x stage of lactation interaction suggested that percent protein and percent fat curves were the same shape for all crossbred groups.

Environmental Effects. Least-squares means for environmental effects on 24-hr milk production and milk composition are presented in table 3. Age of the ewe did not influence 24-hr milk production nor milk composition. Owen (1957) also reported little difference in milk production between 3- and 4-year-old ewes. However, when greater differences in age have been examined, age has been an important factor (Barnicoat et al., 1949c).

The number of lambs suckled significantly influenced 24-hr milk production. Ewes nursing twins produced 22% more milk than ewes nursing singles. This value is within the range reported in other studies, such as 25% (Addleman et al., 1964), 22% (Barnicoat et al., 1949b), 22% (Gardner and Hogue, 1964), 13 to 33% (Gardner and Hogue, 1966), 35% (Peart et al., 1972) and 18 to 41% (Slen et al., 1963). The ability of twin lambs to more completely evacuate the udder early in lactation has been cited as the main factor explaining this difference (Gardner and Hogue, 1964). Ewes giving birth to twins produced the same amount of milk as ewes giving birth to singles when both types nursed the same number of lambs (Alexander and Davies, 1959).

Number of lambs suckled did not affect percent milk protein nor percent milk fat. Gardner and Hogue (1964) reported that ewes of mixed Rambouillet and Columbia breeding with twin lambs secreted milk of significantly higher fat content than those with single lambs. The reverse tendency was observed in a later study (Gardner and Hogue, 1966) with Hampshire and Corriedale ewes, even though the difference was not statistically significant. Peart et al. (1972) concluded that number of lambs suckled did substantially influence fat and protein content of the milk; ewes nursing triplets had the highest percent of milk fat followed by ewes nursing twins and then by ewes nursing singles. This order was reversed for milk protein percent.

Stage of lactation influenced 24-hr milk production and percent milk protein and percent milk fat (P<.01). Figure 1 shows the estimated lactation curve averaged over all crossbred groups. Twenty-four-hour milk production increased to a maximum of 1,795 ml/day at approximately 3 weeks _post partum_ and then decreased steadily to the 15th week when production averaged only 369 ml/day. An initial and rapid increase followed by a peak (attained between 3 and 4 weeks _post partum_) has also been observed in studies by Addleman _et al_. (1964), Barnicoat _et al_. (1949b), Barnicoat _et al_ (1956a), Corbett (1968), Gardner and Hogue (1964, 1966) and Wilson _et al_. (1971).

Percent protein from early, mid and late lactation samples, as well as percent fat representing only mid and late lactation samples[6] increased significantly as lactation progressed; maximum values occurred at the end of the study. Similar results were reported by Barnicoat _et al_. (1949c), who found that after allowing 2 or 3 weeks for the initial effects of colostrum to disappear, the concentration of fat, solids-non-fat, total protein and ash increased during lactation, whereas lactose alone decreased. Corbett (1968) reported that fat and protein content declined in the early weeks of lactation and then rose so that the highest values were observed at the end of lactation, while lactose content showed the opposite trend. In a study by Wilson _et al_. (1971), percent fat increased to the 10th week of lactation while percent protein remained relatively constant.

Ewes free of mastitis produced 11.5% more milk than ewes with mastitis in only one half of the udder and 58.3% more milk than ewes infected in both halves. Gross _et al_. (1978) reported that CMT scores recorded at lambing had no significant association with lamb weaning weight but that scores taken 3 to 7 weeks later approached a significant negative relationship to weaning weight (P<.10). The same trend was found

[6]Milk samples representing early lactation were accidentally lost during laboratory analysis.

in dairy cattle (Braund and Schultz, 1963), where more positive CMT scores were observed in cows producing less than 9 kg per day.

Ewes infected in either one or both halves of the udder had significantly higher percent protein than ewes free of mastitis. A possible explanation for this difference is that in addition to the normal amount of milk protein, there is additional protein in the white blood cells contaminating the milk.

Factors Affecting Mastitis Incidence. Crossbred groups differed in incidence of mastitis ($P<.05$). Cheviot-sired ewes had higher than average incidence, Finnsheep and Romney crossbreds were lower than average, and incidence among Dorset crosses was approximately average (figure 2). Except for Dorsets, mastitis incidence tended to follow sire breed rank for milk production (table 2). There was little difference in incidence between ewes with 1/2 Columbia-type *vs* 1/2 Suffolk inheritance. Overall mastitis incidence of 11.5% in this experiment is similar to the 10% value reported by Gross *et al*. (1978) in a flock of purebred Targhee ewes.

In the spring of 1978, the entire population of 316 ewes from the two grazing management environments to which ewes in the present experiment belonged were administered the California Mastitis Test within 48 hr of lambing. Analysis of variance of those data indicated that breed of a ewe's sire did not significantly influence mastitis incidence. However, as was true in these data, Cheviot and Dorset crosses were above average while Finnsheep and Romney crosses were below average in incidence. On the other hand, breed of the ewe's dam did influence mastitis ($P<.05$), with Suffolk crosses having higher incidence than Columbia-type crosses. Overall incidence was 12.1%, in close agreement to the 11.5% value found in this study.

Other χ^2 tests indicated that mastitis occurred at random with respect to stage of lactation and to number of lambs suckled. This latter observation is not consistent with the findings of Gross *et al*. (1978) that mothers of single lambs showed a lower mean CMT score than mothers of twins. They hypothesized that the higher mean CMT in mothers of twins might be due to increased irritation or injury caused by twin suckling.

Mastitis did not occur at random with respect to repeated observations on the same ewe. More ewes than expected had either no positive CMT scores in eight tests or more than three positive tests. This suggests that certain ewes were resistent to infection while others had chronic cases. Figure 3 shows the distribution of observed _vs_ expected number of positive CMT tests per ewe in eight samplings.

Relationship Between Condition Score and Milk Production. The product-moment correlation between total milk production and subjective condition score was -.25 (not significant). Owen (1957) studied the relationship between weight change during lactation and milk yield of the ewe; his uniformly negative correlation and regression coefficients (though nearly all nonsignificant and ranging from -.15 to -.35) suggested a slightly smaller weight gain during lactation for the heavier milk yielding ewes. Our correlation is in close agreement, both in direction and magnitude, with Owen's results.

LITERATURE CITED

Addleman, D., D. Hutto and R. Bogart. 1964. Milk yield and composition in five breeds of sheep. J. Anim. Sci. 23:900 (Abstr.).

Alexander, G. and H. L. Davies. 1959. Relationship of milk production to number of lambs born or suckled. Australian J. Agr. Res. 10:720.

Barnicoat, C. R., A. G. Logan and A. I. Grant. 1949a. Milk secretion studies with New Zealand Romney ewes. I. Introduction and experimental methods. J. Agr. Sci. 39:44.

Barnicoat, C. R., A. G. Logan and A. I. Grant. 1949b. Milk secretion studies with New Zealand Romney ewes. II. Milk yield of ewes and factors influencing them. J. Agr. Sci. 39:47.

Barnicoat, C. R., A. G. Logan and A. I. Grant. 1949c. Milk secretion studies with New Zealand Romney ewes. III. Composition of New Zealand Romney ewe's milk. J. Agr. Sci. 39:237.

Barnicoat, C. R., P. F. Murray, E. M. Roberts and G. S. Wilson. 1956a. Milk secretion studies with New Zealand Romney ewes. VI. Yield and composition of ewe's milk in relation to growth of the lamb. J. Agr. Sci. 48:12.

Barnicoat, C. R., P. F. Murray, E. M. Roberts and G. S. Wilson. 1956b. Milk secretion studies with New Zealand Romney ewes. VII. A comparison between Romney and 3/4 Cheviot cross ewes. J. Agr. Sci. 48:19.

Braund, D. G. and L. H. Schultz. 1963. Physiological and environmental factors affecting the California Mastitis Test under field conditions. J. Dairy Sci. 46:197.

Cedillo, R. M., W. D. Hohenboken and J. Drummond. 1977. Genetic and environmental effects on age at first estrus and on wool and lamb production of crossbred ewe lambs. J. Anim. Sci. 44:948.

Coombe, J. B., I. D. Wardrop and D. E. Tribe. 1960. A study of milk production of the grazing ewe, with emphasis on the experimental technique employed. J. Agr. Sci. 54:353.

Corbett, J. L. 1968. Variation in yield and composition of milk of grazing Merino ewes. Australian J. Agr. Res. 19:283.

Gardner, R. W. and D. W. Hogue. 1964. Effects of energy intake and number of lambs suckled on milk yield, milk composition and energetic efficiency of lactating ewes. J. Anim. Sci. 23:935.

Gardner, R. W. and D. E. Hogue. 1966. Milk production, milk composition and energetic efficiency of Hampshire and Corriedale ewes fed to maintain body weight. J. Anim. Sci. 25:789.

Geenty, K. G. and K. T. Jagusch. 1974. A comparison of the performance of Dorset, Corriedale and Romney sheep during lactation. Proc. New Zealand Soc. Anim. Prod. 34:14.

Gill, J. L. and H. D. Hafs. 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33:331.

Gross, S. J., E. J. Pollak, J. G. Anderson and D. T. Torell. 1978. Incidence and importance of subclinical mastitis in sheep. J. Anim. Sci. 46:1.

Klinger, R. G. and W. D. Hohenboken. 1978. Sheep management at Oregon State University. Oregon Agr. Exp. Sta. Circular of Information 666.

Langlands, J. P. 1973. Milk and herbage intakes by grazing lambs born to Merino ewes and sired by Merino, Border Leicester, Corriedale, Dorset Horn and Southdown rams. Anim. Prod. 16:285.

McCance, I. 1959. The determination of milk yield in the Merino ewe. Australian J. Agr. Res. 19:283.

Owen, J. B. 1957. A study of the lactation and growth of hill sheep in their native environment and under lowland conditions. J. Agr. Sci. 48:387.

Peart, J. N., R. A. Edwards and E. Donaldson. 1972. The yield and composition of the milk of Finnish Landrace x Blackface ewes. I. Ewes and lambs maintained indoors. J. Agr. Sci. 79:303.

Pollott, G. E. and J. B. Kilkenny. 1976. A note on the use of condition scoring in commercial sheep flocks. Anim. Prod. 23:261.

Robinson, J. J., W. H. Foster and T. J. Forbes. 1969. The estimation of the milk yield of a ewe from body weight data on the suckling lamb. J. Agr. Sci. 72:103.

Slen, S. B., R. D. Clark and R. Hironaka. 1963. A comparison of milk production and its relation to lamb growth in five breeds of sheep. Can. J. Anim. Sci. 43:16.

Warren, E. P. and R. E. Renbarger. 1963. Some factors affecting milk yield of ewes and growth of lambs. J. Anim. Sci. 22:866. (Abstr.).

Wilson, L. L., H. Varela-Alvarez, C. E. Hess and M. C. Rugh. 1971. Influence of energy level, creep feeding and lactation stage on ewe milk and lamb growth characters. J. Anim. Sci. 33:686.

TABLE 1. SPLIT-PLOT ANALYSIS OF VARIANCE FOR GENETIC AND ENVIRONMENTAL EFFECTS ON 24-HR MILK PRODUCTION AND MILK COMPOSITION OF CROSSBRED EWES

Source	df	Mean square x 10^{-3} 24-hr milk production	df	Mean square: % protein	df	Mean square: % fat
Between ewes:						
Breed of the ewe's sire (S)	3	1,377+	3	1.17**	3	.08
Breed of the ewe's dam (D)	1	9	1	3.49**	1	5.85
S x D interaction	3	232	3	.85*	3	4.09
Age of the ewe (A)	1	417	1	.23	1	1.70
S x D x A interaction	-	--	3	.63	3	1.40
No. of lambs suckled (K)	1	4,111**	1	.31	1	.40
S x D x K interaction	-	--	3	.64	3	5.64
Among ewes within subgroups	47	562	41	.25	41	4.54
Within ewes:						
Stage of lactation (L)	7	14,960**	2	9.63**	1	24.55**
S x D x L interaction	21	69	6	.12	3	1.17
Mastitis score	2	1,285**	2	.76**	2	1.04
Residual	346	98	95	.09	71	.81

+P<.10
*P<.05
**P<.01

TABLE 2. LEAST-SQUARES MEANS FOR GENETIC EFFECTS ON 24-HR MILK PRODUCTION AND MILK COMPOSITION

	24-hr milk production	Milk composition	
	ml/day	% protein	% fat
Breed of the ewe's sire:			
Cheviot	1164	4.67	6.66
Dorset	1198	5.04	6.73
Finnsheep	937	4.83	6.57
Romney	1061	5.06	6.64
Breed of the ewe's dam:			
Columbia-type	1095	4.73	6.92
Suffolk	1085	5.07	6.38
Overall mean:	1090	4.90	6.65

TABLE 3. LEAST-SQUARES MEANS FOR ENVIRONMENTAL EFFECTS ON 24-HR MILK PRODUCTION AND MILK COMPOSITION

	24-hr milk production ml/day	Milk composition % protein	% fat
Age of ewe:			
3 years old	1057	4.94	6.79
4 years old	1123	4.86	6.51
No. of lambs suckled:			
Two	1197	4.85	6.58
One	983	4.95	6.72
Stage of lactation: (No. of weeks *post partum*)			
1st week	1579		
3rd week	1795	4.45	
5th week	1515		
8th week	1223	4.94	6.17
10th week	998		
12th week	775	5.31	7.13
14th week	466		
15th week	369		
Mastitis infection:			
Free of infection	1293	4.65	6.34
One udder half infected	1160	5.00	6.46
Both udder halves infected	817	5.05	7.14
Overall mean:	1090	4.90	6.65

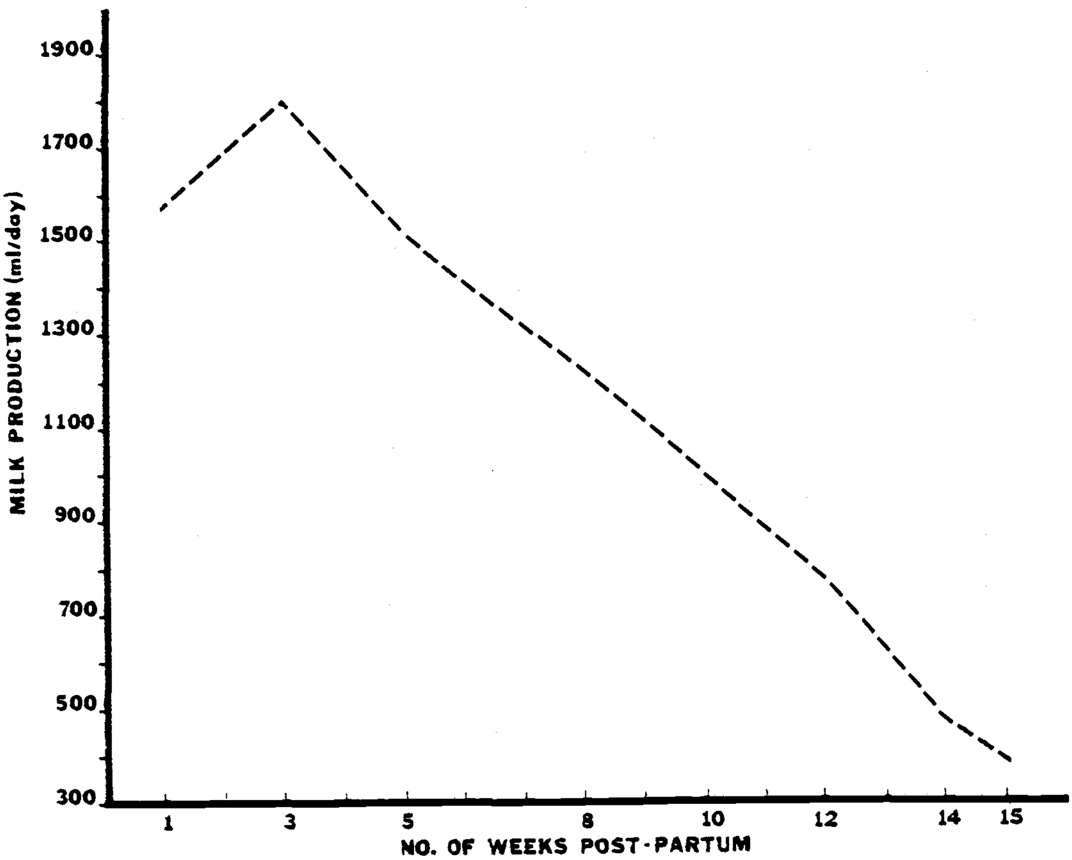

Figure 1. Lactation curve averaged over all crossbred groups.

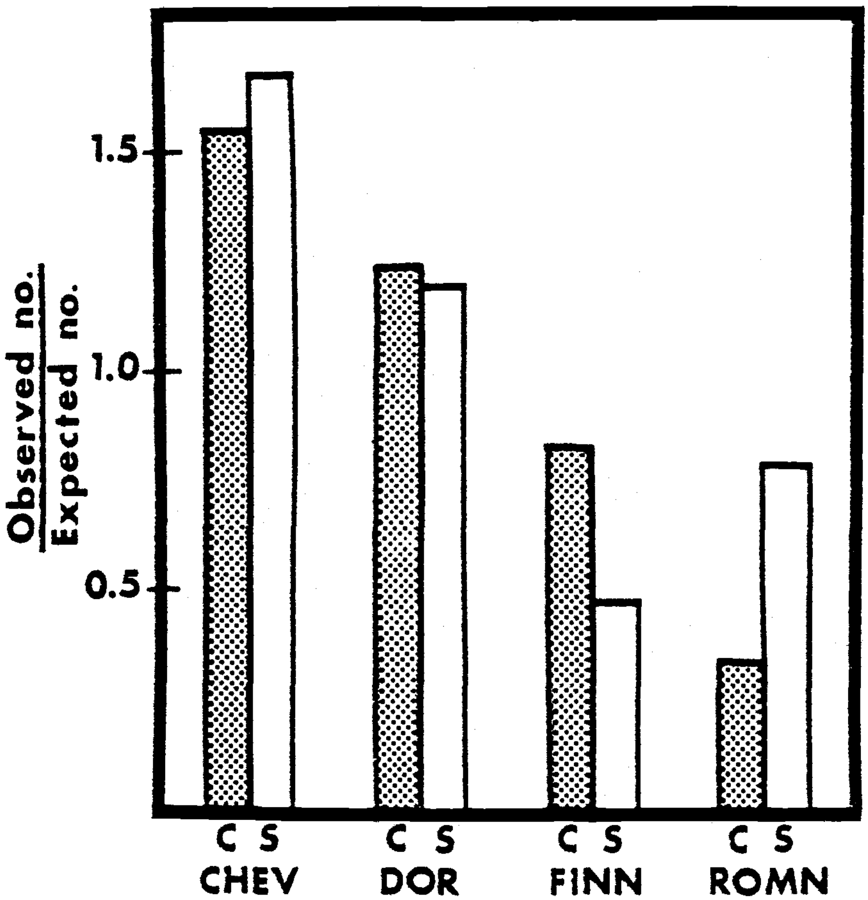

Figure 2. Ratio of observed to expected number of positive mastitis test results for each crossbred group.

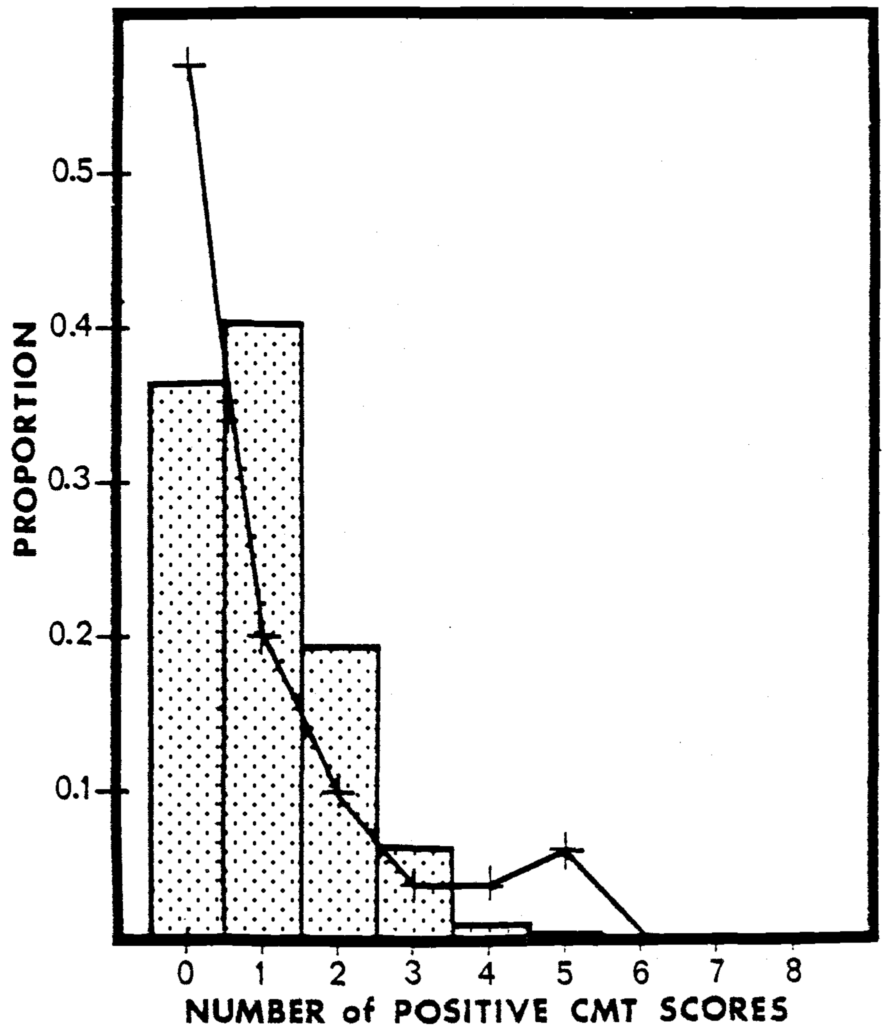

Figure 3. Observed distribution of number of positive CMT tests per ewe compared to expected number of positive tests based upon strictly random occurrence. The histogram is the expected distribution computed from expansion of $(.88 + .12)^8$. Observed distribution is superimposed as a solid line. See text for further explanation.

RELATIONSHIPS BETWEEN EWE MILK PRODUCTION AND COMPOSITION AND PREWEANING LAMB WEIGHT GAIN[1]

Glafiro Torres-Hernandez[2] and William Hohenboken[2]

[1]Technical Paper No. 5255, Oregon Agricultural Experiment Station. Contribution to North-Central Regional Project NC-111, Increased Efficiency of Lamb Production.

[2]Department of Animal Science.

SUMMARY

Fifty-six 3- and 4-year-old ewes from eight crossbred groups were hand milked and their lambs weighed approximately every 2 weeks for a 15-week lactation period to study relationships of ewe milk production (MP), percentage milk protein (PMP) and percentage milk fat (PMF) to preweaning weight gain (G) of single and twin lambs. Regression coefficients of G on MP and corresponding correlations were large and significant toward the start of lactation and generally decreased as lactation progressed. For the entire lactation, regressions of G on MP were .11 kg/l ($P<.05$) and .07 kg/l ($P<.05$), while correlations between G and MP were .64 ($P<.01$) and .55 ($P<.01$) for single and twin lambs, respectively. G of single lambs was predicted most accurately from MP and PMP, while in twin lambs milk composition terms did not improve the precision in predicting G from information on MP alone. Breed of dam influenced G of twin lambs but not of single lambs significantly. Lamb sex did not significantly influence MP nor G. Regression equations to predict milk production from weight gain of single and twin lambs were also obtained. For the entire lactation the regression coefficients were 3.74 l/kg ($P<.05$) and 4.27 l/kg ($P<.05$) for single lambs and twins, with r^2 values of .41 and .30, respectively. Single lambs gained more weight during lactation than the average weight gain of one twin lamb. The total gain of twin sets, however, was much greater than gain of a single lamb.

(Key Words: Milk Production, Milk Composition, Lamb Gain.)

INTRODUCTION

In sheep, preweaning weight gain of the offspring is influenced by milk production of the dam (Burris and Baugus, 1955, Barnicoat et al., (1956d). Results from a milk production experiment conducted with 8 groups of crossbred ewes were reported previously by Torres-Hernandez and Hohenboken (1979). The purpose of the present study is to present subsequent results from that same experiment dealing with the relationship between milk production and milk composition of the ewes and preweaning weight gain of the lambs.

Specific objectives of this study are: 1) to determine the relationship between ewe milk production and preweaning weight gain of single and of twin lambs, at different stages of lactation and for the entire preweaning period, 2) to determine effects of milk composition, alone or in combination with milk production, on preweaning weight gain of single and of twin lambs, 3) to determine the effects of crossbred type of ewe and of lamb sex on preweaning weight gain of single and of twin lambs and 4) to compute the regression of milk production on single and on twin lamb weight gain.

MATERIALS AND METHODS

Population and Management. Fifty-six 3- and 4-year-old ewes from crosses of North Country Cheviot, Dorset, Finnsheep and Romney rams on Suffolk and Columbia-type range ewes were utilized in this experiment. All lambs born from these ewes were 3-breed crosses with a common 50% Hampshire inheritance. Management and milking procedures of the experimental flock were discussed by Torres-Hernandez and Hohenboken (1979). Throughout lactation lambs were allowed access to irrigated pasture and to a high grain, pelleted ration. Their dams had access to irrigated pasture but not to supplemental feed.

Lamb weights were individually recorded at birth, at 1 week postpartum and approximately every 2 weeks thereafter until weaning, in accordance with the days their dams were milked. Lamb weight gains were computed as lamb weight at time t+1 minus lamb weight at time t. For ewes with twins, lamb weight gain in subsequent analyses was the total weight gain of both twins in the set. Milk production for the same period (t to t+1) was computed as estimated daily milk yield at time t times half the number of days from t to t+1 plus estimated daily milk yield at time t+1 times that same number of days.

Statistical Analyses. Least-squares procedures were utilized in the statistical analyses. To accomplish the first objective, the analysis of variance utilized the following model:

$$G = M + D + S + b(MP) + E \quad (1)$$

where:

G = lamb weight gain,

M = overall mean

D = breed of dam (with seven degrees of freedom for the eight crossbred ewe groups),

S = sex of lamb,

MP = milk production (as a covariate),

b = the regression coefficient associated with the covariate and

E = random error.

For the second objective, analyses of variance were performed using the following models:

$$G = M + D + S + b(MP) + b(PMP) + E \quad (2)$$

$$G = M + D + S + b(MP) + b(PMF) + E \quad (3)$$

$$G = M + D + S + b(MP) + b(PMP) + b(PMF) + E \quad (4)$$

$$G = M + D + S + b(PMP) + E \quad (5)$$

$$G = M + D + S + b(PMF) + E \quad (6)$$

$$G = M + D + S + b(PMP) + b(PMF) + E \quad (7)$$

where:

G, M, D, S, MP, b, E are defined as before,

PMP = percentage milk protein (as a covariate) and

PMF = percentage milk fat (as a covariate).

These analyses were used to determine whether milk composition added information in predicting G to that from MP alone, or whether composition terms could replace MP without sacrificing precision. In research or production schemes, composition would be much easier to measure than MP.

All of the analyses were run separately for ewes nursing single lambs and for those nursing twins. Consequently, the number of degrees of freedom for lamb sex in the first category was one (male or female), while in the second category it was two (2 males or 2 females or 1 male plus 1 female). Age of the ewe (3 vs. 4 years) was not included in the analyses, because previous results indicated that it did not influence 24-hr milk production nor milk composition.

The model 1 analysis was run for each stage of lactation (corresponding to the first through the eighth milking) as well as for the entire lactation. Model 2 through 7 analyses were run only for the entire lactation. Correlations between MP and G of single and twin lambs for each stage of lactation as well as for the entire lactation were computed on a within breed of dam and within lamb sex basis as the geometric mean of the regression of G on MP and the regression of MP on G.

Results from model 1 through 7 analyses were used to accomplish the third objective.

For the fourth objective, the mathematical model included MP as the dependent variable and D, S, and G as independent variables. This model was used for analysis of variance at each stage of lactation as well as for the entire lactation, separately for ewes nursing singles and for ewes nursing twins. To regress milk production on weight gain is counter to the expected biological cause and effect relationship. We publish these equations and associated r^2 values, however, to aid investigators who might wish to estimate milk production, which is costly and difficult to measure, from lamb weight gain, which is much easier to measure.

RESULTS AND DISCUSSION

Objective 1. Regression coefficients of G on MP and associated r^2 values are presented in table 1. Both regression coefficients and coefficients of determination tended to decrease as lactation progressed. For the entire lactation, lamb weight gain increased .11 kg ($P<.05$) for single lambs and .07 kg ($P<.05$) for twins for each additional liter of milk produced by the ewe.

Correlations between lamb weight gain and milk production, for both single lambs and twins, are also given in table 1. Correlations were large and significant toward the start of lactation and tended to decrease in magnitude as lactation progressed. For the entire lactation, they equalled .64 ($P<.01$) and .55 ($P<.01$) for single and twin lambs, respectively. These results suggest a decreasing dependence of lambs on milk and increasing dependence of lambs upon forage or creep feed with advancing lamb age. Both quantitatively and qualitatively, our results are in agreement with those of Barnicoat et al. (1949), Burris and Baugus (1955), Barnicoat et al. (1956a, 1956d), Owen (1957), Coombe et al. (1960), Munro (1962), Slen et al. (1963), Folman et al. (1966a, 1966b), Moore (1966), Peart (1967, 1968), Scales (1968), Butterworth et al. (1968), Robinson et al. (1969), Acharya and Bawa (1971), Geenty and Jagusch (1974) and Peart et al. (1975) that ewe milk production is the most important variable influencing lamb weight gain in the early stages of lactation but that the effect of milk production tends to decline as lambs become more dependent upon the intake of forage or grain.

Objective 2. Regression coefficients of total lactation G on MP, PMP and PMF, as well as associated R^2 values for model 2 through 7 analyses, are presented in table 2; results from the model 1 analysis are included for purposes of comparison. The addition of PMP to model 2 as a continuous variable added to the R^2 value in single lambs (from .73 in model 1 to .86 in model 2) but not in twins (.71 for both models). The addition of PMF to model 3 had little effect on R^2 in single lambs (.73 vs. .74) and no effect in twins (.71 for both models). Model 4, which included both PMP and PMF in addition to MP, was no more effective in explaining variation in G than model 2 in single lambs or model 1 in twins.

With MP in the model for single lambs, the regression coefficient of total lactation G on PMP was large and positive. PMP, however, had a residual standard deviation of only .30%, so the effect of variation in PMP on observed variation in G was not large. Also in single lambs, with MP in the model the regression of G on PMF was negative but small. With MP in the models for twin lambs, regression coefficients of G on PMP and PMF were the same sign as corresponding regressions in single lambs, but the coefficients were very small.

The deletion of MP (models 5 through 7) resulted in a loss of precision compared to models in which MP was included (models 2 through 4). None of the regressions of G on PMP or PMF was significant, in either single lambs or twins. Our results are in agreement with those obtained by Barnicoat et al. (1956b), Slen et al. (1963) and Moore (1966) that there was little improvement in the relationship between milk intake and growth rate when MP was expressed in terms of components rather than whole milk. Scales (1968), however, reported a highly significant correlation between fat intake and lamb growth in Romney lambs but not in Corriedales and Merinos.

An interesting observation was that in twins, dropping MP from the model caused the regression of G on PMP to change from a small positive to a moderate negative value. The correlation between milk component percentages and milk quantity generally is negative. Models 5 and 7 allowed MP to vary, so under those conditions higher PMP would be associated with lower MP and therefore lower G.

Objective 3. For the entire lactation G, no significant differences due to breed of dam were observed for single lambs, but differences did exist ($P<.01$) among crossbred groups for G of twins (table 3). Lambs from ewes with Dorset (49.6 kg, average weight of both lambs) and Romney (48.2 kg) sires were heaviest, followed by lambs from ewes with Finnsheep (46.2 kg) and Cheviot (41.5 kg) sires. Furthermore, lambs from ewes with Suffolk (48.3 kg) dams had greater weight gains than lambs from ewes with Columbia (44.5 kg) dams. Inclusion of MP as a covariate in these analyses had the effect of removing from the least-squares means those differences in lamb weight gain attributable to differences in milk production. Thus, breed of dam effects are predominantly a measure of the average effects of genes for lamb growth transmitted from crossbred ewes to their offspring.

Geenty and Jagusch (1974) compared growth of Dorset, Corriedale and Romney twin lambs until weaning at 12 weeks of age. The Dorset lambs were 6% heavier than Corriedales and 13% heavier than Romneys at weaning; these differences represented both the effects of differences among breeds in milk production and differences among lamb breeds in growth potential.

In the model 1 analysis, breed of ewe did not affect single lamb G significantly, but in models 2 and 4, the ewe breed effect was significant. In other words, within ewes whose MP and PMP were held constant mathematically, variation was expressed among ewe breeds in weight gain of their single lambs. Including both MP and PMP in the model, since they were negatively correlated, might have cancelled their effects on G within breeds, thereby allowing breed differences in breeding value for growth transmitted to the lambs to be expressed. For twins, dam breed differences in G were significant regardless of whether milk components were included in the models or not.

For neither singles nor twins were sex differences a significant source of variation in G. For single lambs, deviations were in the order and of the magnitude reported in the literature (Butterworth et al., 1968; Levine and Hohenboken, 1978). That is, males gained more than females. The difference for the entire lactation was 2.2 kg. Differences in total weight gain for twin sets of two males (46.9 kg), two females (47.4 kg) or one lamb of each sex (45.6 kg) were not significant.

Objective 4. Regression equations to predict milk production from weight gain of single and twin lambs, on a within breed of dam and lamb sex basis, are presented in table 4. Neither ewe breed nor lamb sex influenced MP significantly in either single-rearing or twin-rearing ewes. For week 1 postpartum, the regression coefficients indicated that single lambs and twin sets gaining one kilogram more than average had dams whose MP was 5.06 and 4.98 liters above average, respectively. These regressions explained 65 and 69% of the total variation in week 1 MP. The magnitude and significance of the regression coefficients tended to decrease as lactation progressed, but only in the last week were they negative (though not significant). For the entire lactation, regression coefficients were 3.74 l/kg ($P<.05$) and 4.27 l/kg ($P<.05$) with r^2 values of .41 and .30, respectively.

The estimation of ewe milk production using information on lamb growth has been investigated by Barnicoat et al. (1956c) and Doney and Munro (1962). Different approaches, however, have been attempted by other investigators. Owen (1957) included lamb birth weight, ewe udder width and ewe weight as independent variables influencing milk production, while Robinson et al. (1969) estimated daily milk consumption of the lamb as a function of lamb body weight and lamb body weight change.

CONCLUSIONS

1. This study confirms a positive relationship between ewe milk production and lamb weight gain. Both regression and correlation coefficients relating G to MP were larger in single lambs than in twin lambs. Although ewes rearing twins produce more milk throughout lactation than ewes rearing a single lamb (figure 1), less milk is available to each twin lamb than to each single lamb. MP is therefore more a limiting factor for G in twin than in single lambs, and the relationship between MP and G is expected to be lower.

2. Weight gain of single lambs was predicted most accurately from information on both MP and PMP, whereas in twin lambs information from milk composition terms did not improve the precision in predicting G to that from information on MP alone.

3. Milk production was predicted from G with relatively good accuracy, as evidenced by r^2 values of .41 and .30 for ewes nursing single lambs and for those nursing twin lambs, respectively.

4. For the entire lactation, regression coefficients showed that for each additional kilogram of weight gain in single and twin lambs, 9.1 (the reciprocal of b = .11) and 14.3 (the reciprocal of b = .07) additional liters of milk, respectively, were required from their dams. Consequently, increasing weaning weight of lambs by increasing MP is likely to be expensive. To increase MP, sheep producers have the options of within breed selection, crossbreeding schemes utilizing breeds with high MP potential, improved nutrition, improved health management or various combinations thereof. More research is needed to determine the efficacy and cost of alternatives to increase MP and thereby G in sheep.

5. Except for the last week of lactation, lamb average daily gain was always greater for single lambs than for twins (figure 1). The superiority of single lambs decreased as lactation progressed, however. This observation suggests earlier and greater intake of solid feeds by twin lambs, as has been reported by Maxwell et al., (1979). Single

lambs gained more weight during lactation than the average weight gain of one twin lamb. The total gain of twin sets, however, was much greater than that of a single lamb.

LITERATURE CITED

Acharya, R.M. and S.J.S. Bawa. 1971. Milk production of ewes and its relationship with preweaning growth of lambs. Indian J. Anim. Sci. 41:572.

Barnicoat, C.R., A.G. Logan and A.I. Grant. 1949. Milk secretion studies with New Zealand Romney ewes. IV. Milk secretion in relation to growth of the lamb. J. Agr. Sci. Camb. 39:237.

Barnicoat, C.R., P.F. Murray, E.M. Roberts and G.S. Wilson. 1956a. Milk secretion studies with New Zealand Romney ewes. VII. A comparison between Romney and 3/4 Cheviot cross ewes. J. Agr. Sci. Camb. 48:19.

Barnicoat, C.R., P.F. Murray, E.M. Roberts and G.S. Wilson. 1956b. Milk secretion studies with New Zealand Romney ewes. V. Experimental. J. Agr. Sci. Camb. 48:10.

Barnicoat, C.R., P.F. Murray, E.M. Roberts and G.S. Wilson. 1956c. Milk secretion studies with New Zealand Romney ewes. X. Indirect method of assessing milk yields of grazing ewes. J. Agr. Sci. Camb. 48:27.

Barnicoat, C.R., P.F. Murray, E.M. Roberts and G.S. Wilson. 1956d. Milk secretion studies with New Zealand Romney ewes. VI. Yield and composition of ewe's milk in relation to growth of the lamb. J. Agr. Sci. Camb. 48:12.

Burris, M.J. and C.A. Baugus. 1955. Milk consumption and growth of suckling lambs. J. Anim. Sci. 14:186.

Butterworth, M.H., T.R. Houghton, J.C. Macartney, A.J. Prior, C.P. Middlemiss and D.E. Edmonds. 1968. Some observations on the lactation of Blackhead ewes and the growth of lambs: the composition and yield of milk. J. Agr. Sci. Camb. 70:203.

Coombe, J.B., I.D. Wardrop and D.E. Tribe. 1960. A study of milk production of the grazing ewe, with emphasis on the experimental technique employed. J. Agr. Sci. Camb. 54:353.

Doney, J.M. and J. Munro. 1962. The effect of suckling, management and season on sheep milk production as estimated by lamb growth. Anim. Prod. 4:215.

Folman, Y., E. Eyal and R. Volcani. 1966a. Mother-offspring relationships in Awassi sheep. II. Milk yields and weight gains of lambs in a mutton flock. J. Agr. Sci. Camb. 67:369.

Folman, Y., E. Eyal and R. Volcani. 1966b. Mother-offspring relationships in Awassi sheep. III. The effect of different suckling regimes and weaning age on weight gains of lambs in dairy flocks. J. Agr. Sci. Camb. 67:371.

Geenty, K.G. and K.T. Jagusch. 1974. A comparison of the performance of Dorset, Corriedale and Romney sheep during lactation. Proc. New Zealand Soc. Anim. Prod. 34:14.

Levine, J.M. and W. Hohenboken. 1978. Crossbred lamb production from Columbia and Suffolk ewes. I. Ewe production and lamb traits. J. Anim. Sci. 47:89.

Maxwell, T.J., J.M. Doney, J.A. Milne, J.N. Peart, A.J.F. Russell, A.R. Sibbald and D. MacDonald. 1979. The effect of rearing type and prepartum nutrition on the intake and performance of lactating Greyface ewes at pasture. J. Agr. Sci. Camb. 92:165.

Moore, R.W. 1966. Milk quality in Merino and Corriedale ewes. Australian J. Agr. Res. 17:201.

Munro, J. 1962. A study of the milk yield of three strains of Scottish Blackface ewes in two environments. Anim. Prod. 4:203.

Owen, J.B. 1957. A study of the lactation and growth of hill sheep in their native environment and under lowland conditions. J. Agr. Sci. Camb. 48:387.

Peart, J.N. 1967. The effect of different levels of nutrition during late pregnancy on the subsequent milk production of Blackface ewes and on the growth of their lambs. J. Agr. Sci. Camb. 68:365.

Peart, J.N. 1968. Lactation studies with Blackface ewes and their lambs. J. Agr. Sci. Camb. 70:87.

Peart, J.N., J.M. Doney and A.J. Macdonald. 1975. The influence of lamb genotype on the milk production of Blackface ewes. J. Agr. Sci. Camb. 84:313.

Robinson, J.J., W.H. Foster and T.J. Forbes. 1969. The estimation of the milk yield of a ewe from body weight data on the suckling lamb. J. Agr. Sci. Camb. 72:103.

Scales, G.H. 1968. Lactation performances of Romney, Corriedale, and Merino ewes in a tussock grassland environment. New Zealand J. Agr. Res. 11:155.

Slen, S.B., R.D. Clark and R. Hironaka. 1963. A comparison of milk production and its relation to lamb growth in five breeds of sheep. Can. J. Anim. Sci. 43:16.

Torres-Hernandez, G. and W. Hohenboken. 1979. Genetic and environmental effects on milk production, milk composition and mastitis incidence in crossbred ewes. J. Anim. Sci. 49:In press.

TABLE 1. REGRESSION COEFFICIENTS OF SINGLE AND TWIN LAMB WEIGHT GAIN ON MILK PRODUCTION WITH CORRESPONDING COEFFICIENTS OF DETERMINATION AND CORRELATION.

No. of weeks postpartum	Singles			Twins		
	$b_{G.MP}$	r^2	r	$b_{G.MP}$	r^2	r
1	.13**	.65	.81**	.14**	.69	.83**
3	.04	.12	.35	.10**	.32	.57**
5	.10*	.30	.55*	.01	.01	.08
8	.10*	.33	.58**	.11*	.20	.45*
10	.01	.00	.04	.00	.00	.00
12	.25*	.30	.55**	.03	.01	.11
14	.43*	.37	.61**	.19	.06	.24
15	-.04	.00	-.05	-.17	.03	-.18
Entire lactation	.11*	.41	.64**	.07*	.30	.55**

*P<.05
**P<.01

TABLE 2. REGRESSION COEFFICIENTS OF GAIN ON MILK PRODUCTION, PERCENT MILK PROTEIN AND PERCENT MILK FAT, AND CORRESPONDING MULTIPLE CORRELATION COEFFICIENTS

	MODEL NO.						
	1	2	3	4	5	6	7
				Singles			
$b_{G.MP}$	.11*	.14**	.12*	.15**			
$b_{G.PMP}$		5.31*		5.23*	2.81		2.94
$b_{G.PMF}$			-.40	-.24		.10	.25
R^2	.73	.86	.74	.86	.57	.53	.57
				Twins			
$b_{G.MP}$	.07*	.07*	.07*	.07*			
$b_{G.PMP}$		.32		.32	-2.43		-2.38
$b_{G.PMF}$			-.04	-.04		-.22	-.15
R^2	.71	.71	.71	.71	.62	.59	.62

*P<.05
**P<.01

TABLE 3. LEAST-SQUARES MEANS FOR TOTAL LACTATION WEIGHT GAIN OF SINGLE AND TWIN LAMBS BY BREED OF DAM (MODEL 1)

Breed of dam	Singles (kg)	Twins[a] (kg)	Average weight gain of one twin (kg)
Cheviot x Columbia	26.07	39.08	19.54
Dorset x Columbia	26.75	48.60	24.30
Finnsheep x Columbia	24.80	43.34	21.67
Romney x Columbia	25.80	47.02	23.51
Cheviot x Suffolk	31.52	44.03	22.02
Dorset x Suffolk	26.53	50.58	25.29
Finnsheep x Suffolk	23.63	49.02	24.51
Romney x Suffolk	30.74	49.45	24.73
Overall Mean	28.77	46.72	23.36

[a] Numbers for twins represent weight gain of both lambs.

TABLE 4. REGRESSION EQUATIONS TO PREDICT MILK PRODUCTION PER DAY FROM LAMB GAIN, AND CORRESPONDING COEFFICIENTS OF DETERMINATION

No. of week postpartum	SINGLES Equation	r^2	TWINS Equation	r^2
1	$\hat{MP} = 0.17 + 5.06\ G$ **	.65	$\hat{MP} = 0.03 + 4.98\ G$ **	.69
3	$\hat{MP} = 0.55 + 3.22\ G$	.12	$\hat{MP} = 0.43 + 3.31\ G$ **	.32
5	$\hat{MP} = 0.92 + 3.03\ G$ *	.30	$\hat{MP} = 1.65 + 0.61\ G$	.01
8	$\hat{MP} = 0.42 + 3.45\ G$ *	.33	$\hat{MP} = 0.63 + 1.89\ G$ *	.20
10	$\hat{MP} = 1.24 + 0.16\ G$	.00	$\hat{MP} = 1.43 + 0.08\ G$	.00
12	$\hat{MP} = 0.58 + 1.21\ G$ *	.30	$\hat{MP} = 0.92 + 0.43\ G$	.01
14	$\hat{MP} = 0.64 + 0.88\ G$ *	.37	$\hat{MP} = 0.82 + 0.31\ G$	.06
15	$\hat{MP} = 0.58 - 0.07\ G$	.00	$\hat{MP} = 0.72 - 0.21\ G$	.03
Entire lactation	$\hat{MP} = 0.22 + 3.74\ G$ *	.41	$\hat{MP} = -0.43 + 4.27\ G$ *	.30

*$P<.05$
**$P<.01$

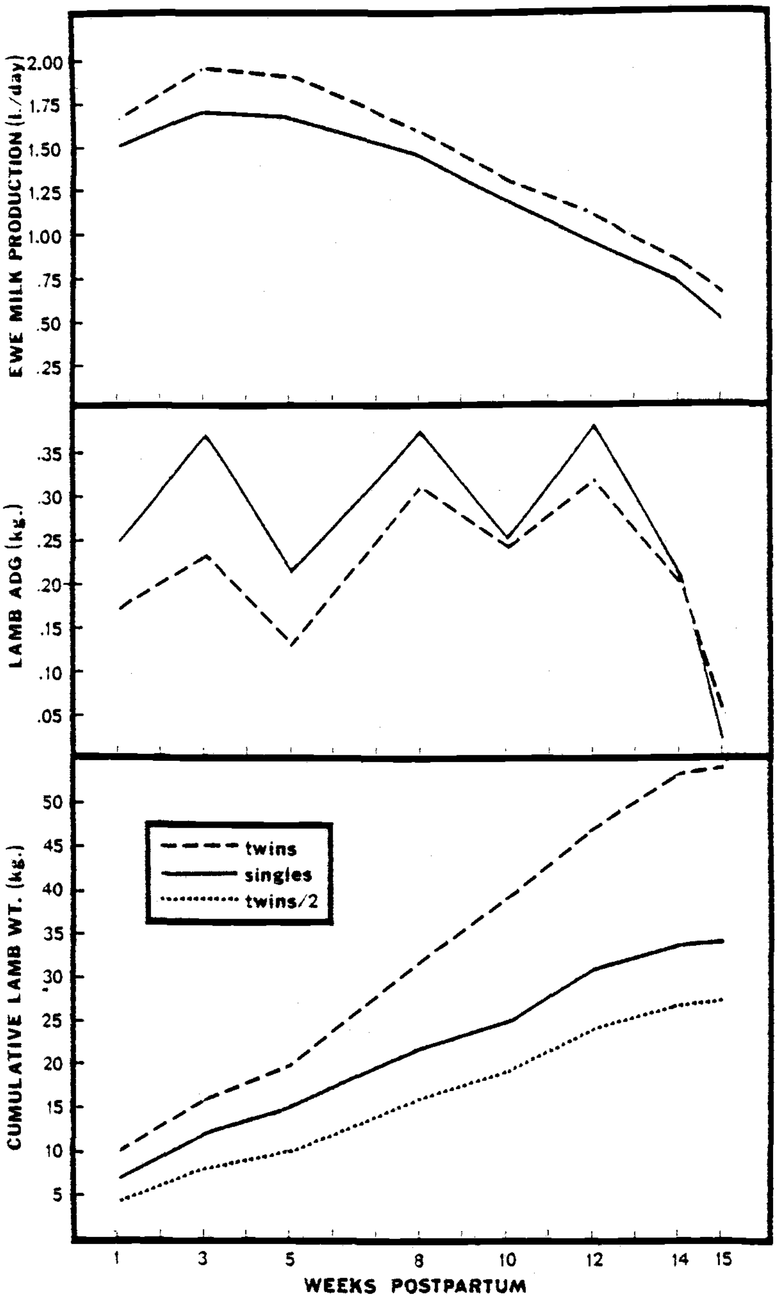

Figure 1. Ewe milk production, lamb average daily gain and cumulative lamb weight for singles and twins throughout lactation.

BIOMETRIC PROPERTIES OF LACTATIONS IN EWES RAISING SINGLE OR TWIN LAMBS[1]

Glafiro Torres-Hernandez[2] and William Hohenboken[2]

[1]Technical Paper No. 5256, Oregon Agricultural Experiment Station. Contribution to North-Central Regional Project NC-111, Increased Efficiency of Lamb Production.

[2]Department of Animal Science.

SUMMARY

The lactation curves of 21 single- (SR) and 28 twin-rearing (TR) ewes were fitted, and their milk production was estimated by the model $Y = ax^{b}e^{-cx}$, developed in England for dairy cattle. In addition, persistency of lactation of SR and TR ewes was compared by five procedures reported in the literature. Results indicated that the coefficients that characterize the shape of the lactation curve (b and c values) were of similar magnitude to those reported in dairy cattle, thus defining a curve of similar shape. Near parallelism between curves of SR and TR ewes was observed throughout lactation, with more milk production from TR ewes. The correlation was .98 ($P<.01$) between total milk production estimated by this model and that based on the sum of partial lactations, although slightly more precision was obtained from the latter method. Lactations of SR ewes had similar persistency to those of TR ewes.

INTRODUCTION

The purpose of the study reported herein was to compare biometric properties of lactation of single-rearing versus twin-rearing crossbred ewes. Specific objectives were: 1) using a model proposed by Wood (1967), to characterize shapes of the lactation curves, 2) using the same model, to estimate total lactation milk yields and 3) using various procedures reported in the literature, to compare persistencies of lactation of single-rearing versus twin-rearing ewes.

MATERIAL AND METHODS

This study utilizes data from an experiment conducted with 56 3- and 4-year-old crossbred ewes (from North Country Cheviot, Dorset, Finnsheep and Romney rams mated to Suffolk and Columbia-type range ewes) all raising 50% Hampshire crossbred lambs. Milk production in the ewes was estimated by hand milking after injection of oxytocin at weeks 1, 3, 5, 8, 10, 12, 14 and 15 postpartum. Results were published in a previous paper (Torres-Hernandez and Hohenboken, 1979), which provides more detailed description of experimental methods and management of the ewes. Data for this study are restricted to milk production from 49 ewes (21 nursing singles and 28 nursing twins), since 7 ewes did not have complete lactation records. Breed of dam is not considered in subsequent analyses since breed effects did not materially influence milk production (Torres-Hernandez and Hohenboken, 1979).

To accomplish the first objective, the following model developed by Wood (1967) was used:

$$Y(x) = ax^{b}e^{-cx} \qquad (1)$$

where Y(x) is milk production on the xth day of lactation, e is the base of natural logarithms and a, b and c are constants. Of these constants, a represents a scaling factor or milk production at the start of lactation, while b and -c represent the limiting slope of the curve before and after the peak of lactation, respectively. By logarithmic transformation equation (1) was linearized to the form:

$$\ell n\ Y(x) = \ell n\ a + b\ \ell n\ x - cx \qquad (2)$$

From equation (2), the constants ℓn a, b and c were estimated from multiple regression analysis within ewes raising single lambs (SR) and within ewes raising twin lambs (TR). Equating the first derivative of equation 2 (with respect to x) to zero and solving for x, the solution is $x = b/c$. Substituting this value into equation 1, maximum milk production is estimated to equal:

$$Ymax = a(b/c)^{b}\ e^{-b} \qquad (3)$$

where b/c is the estimated day that maximum milk production is achieved.

Lactation curves for SR and for TR ewes (Figure 1) were generated using values for a, b and c estimated from the solution of equation 2 for the two types of lactations.

For the second objective, individual a, b and c values fitted for each of the 49 ewes were used in equation 1 to compute milk production each day of the entire 109-day lactation period. Daily milk production was summed to estimate total lactation milk production for each ewe. For purposes of comparison, the correlation was computed between estimates of individual milk production obtained by this method and estimates of individual milk production from the earlier study (Torres-Hernandez and Hohenboken, 1979). Those estimates, hereafter called the cumulative method, were computed as 24-hr milk production per milking, times the appropriate number of days bracketing each milking, summed over the eight times per ewe that milk production was estimated. In addition, several descriptive statistics were computed of milk production estimates by the two methods.

For the third objective, the persistency of lactation of SR and TR ewes was compared by the following procedures:

1. $S = -(b+1)\ \ell n\ c$ (Wood, 1968)
2. $R_{2:1}$, or ratio between milk production obtained in the second third of lactation and that obtained in the first third (Madsen, 1975)
3. $R_{3:1}$, or ratio between milk production obtained in the last third of lactation and that obtained in the first third (Madsen, 1975)

4. $\hat{\beta}_{MP/D}$, or regression of milk production on day of lactation, from day 20 onwards (Louda and Doney, 1976).
5. $MP_{20:109}$, or the proportion of estimated 109-day lactation yield completed in the first 20 days (Frood and Croxton, 1978).

RESULTS

The partial regression coefficients ℓn a, b and c obtained for each type of rearing group are presented in Table 1. Lactation curves for SR and TR ewes, fitted using these coefficients, are shown in Figure 1.

Estimated b/c and Ymax values were computed for each ewe within each type of rearing group. In lactations of 5 SR ewes and of 3 TR ewes, observed maximum production occurred at the first sampling or approximately the sixth day of lactation; by definition, we recorded day of lactation at that sampling rather than at b/c as their day of peak production. Average values for day of peak production and maximum daily milk production (Ymax) were 16.0 days and 1.86 ℓ for SR ewes and 16.9 days and 2.09 ℓ for TR ewes.

The correlation was .98 ($P<.01$) between estimates of total milk production estimated by application of Wood's model and by the cumulative method. Associated descriptive statistics are presented in Table 2.

A summary of results for persistency of lactation of SR vs TR ewes is presented in Table 3. Methods 2 through 5 required estimation of milk production for certain periods of the total lactation. To do so, the cumulative procedure was utilized in methods 2, 3 and 5 while Wood's model was utilized in method 4.

DISCUSSION

Estimates of the coefficients that characterize the shape of the lactation curve (b and c values) in this study are within the range of values reported for both constants in dairy cattle by Wood (1969, 1970, 1976), Cobby and Le Du (1978), Frood and Croxton (1978) and Rao and Sundaresan (1979). This observation confirms similarity between the two species in shape of the lactation curve. Cobby and Le Du

(1978) obtained estimates of a, b and c both by non-linear least squares estimation (equation 1) and by log least squares estimation (equation 2). They reported that neither curve accurately described the entire lactation but that non-linear least squares estimation was more satisfactory over most of the range.

Three conclusions can be drawn from examination of the curves in Figure 1. First, TR ewes produced more milk than SR ewes, a result that has been reported by several authors (reviewed by Torres-Hernandez and Hohenboken, 1979). Secondly, the higher milk production of TR ewes was expressed throughout lactation. Thirdly, the curves were essentially parallel throughout lactation.

Estimated values of 16.0 and 16.9 for day of peak production of SR and TR ewes, respectively, are in good agreement with the 21st day of lactation reported by several authors as the approximate day of peak production estimated by the cumulative method (Barnicoat et al., 1949; Barnicoat et al., 1956; Gardner and Hogue, 1964, 1966; Corbett, 1968; Wilson et al., 1971).

From comparison of the two procedures used to estimate total production per ewe, it would appear that the methods give similar results, as evidenced by the correlation of .98 ($P<.01$) between estimates. Both procedures yielded distributions of milk production that did not deviate significantly from normality. Coefficients of variation indicate that the cumulative method is slightly more precise. A possible explanation for this difference may be the large variation of the intercept values (ℓn a in equation 2) as indicated by coefficients of variation of 111 and 93% for SR and TR ewes, respectively.

Results from Table 3 indicate that lactations of SR ewes had similar persistency to those of TR ewes. This conclusion is verified by examination of Figure 1. Although little difference in $\hat{\beta}_{MP/D}$ between SR and TR ewes was found, the trend is in agreement with results of Louda and Doney (1976), who reported that regression coefficients for SR ewes were significantly lower (closer to zero) than those for TR ewes in Improved Valachian sheep. Furthermore, these authors confirmed their results by examining data from Border Leicester x Cheviot (Hadjipieris et al., 1966), Scottish Blackface (Peart, 1968), Chios (Louca, 1972) and Australian Merino ewes (Langlands, 1973). In addition, Peart et al.

(1979) reported that in both Blackface and Blackface x East Friesland crossbred ewes, the reduction in daily MP as lactation progressed was greater in TR than SR ewes. Doney and Peart (1976), however, showed an effective extension of 2-3 weeks of peak lactation from fostering 24-day-old lambs onto newly-lambed nurse ewes. In addition, the fostered lambs responded by taking more milk in latter stages of lactation.

LITERATURE CITED

Barnicoat, C.R., Logan, A.G. and Grant, A.I. 1949. Milk secretion studies with New Zealand Romney ewes. II. Milk yield of ewes and factors influencing them. J. agric. Sci., Camb. 39:47-55.

Barnicoat, C.R., Murray, P.F., Roberts, E.M. and Wilson, G.S. 1956. Milk secretion studies with New Zealand Romney ewes. VI. Yield and composition of ewe's milk in relation to growth of the lamb. J. agric. Sci., Camb. 48:12-35.

Cobby, J.M. and Le Du, Y.L.P. 1978. On fitting curves to lactation data. Anim. Prod. 26:127-133.

Corbett, J.L. 1968. Variation in yield and composition of milk of grazing Merino ewes. Aust. J. agric. Res. 19:283-294.

Doney, J.M. and Peart, J.N. 1976. The effect of sustained lactation on intake of solid food and growth rate of lambs. J. agric. Sci., Camb. 87:511-518.

Frood, M.J. and Croxton, D. 1978. The use of condition-scoring in dairy cows and its relationship with milk yield and live weight. Anim. Prod. 27:285-291.

Gardner, R.W. and Hogue, D.E. 1964. Effects of energy intake and number of lambs suckled on milk yield, milk composition and energetic efficiency of lactating ewes. J. Anim. Sci. 23:935-942.

Gardner, R.W. and Hogue, D.E. 1966. Milk production, milk composition and energetic efficiency of Hampshire and Corriedale ewes fed to maintain body weight. J. Anim. Sci. 25:789-795.

Hadjipieris, G., Jones, J.G.W., Wimble, R.H. and Holmes, W. 1966. Studies on feed intake and feed utilization by sheep. II. Utilization of feed by ewes. J. agric. Sci., Camb. 66:341-349.

Langlands, J.P. 1973. Milk and herbage intakes by grazing lambs born to Merino ewes and sired by Merino, Border Leicester, Corriedale, Dorset Horn and Southdown rams. Anim. Prod. 16:285-291.

Louca, A. 1972. The effect of suckling regime on growth rate and lactation performance of the Cyprus Fat-tailed and Chios sheep. Anim. Prod. 15:53-59.

Louda, F. and Doney, J.M. 1976. Persistency of lactation in the Improved Valachian breed of sheep. J. agric. Sci., Camb. 87:455-457.

Madsen, O. 1975. A comparison of some suggested measures of persistency of milk yield in dairy cows. Anim. Prod. 20:191-197.

Peart, J.N. 1968. Some effects of live weight and body condition on the milk production of Blackface ewes. J. agric. Sci., Camb. 70:331-338.

Peart, J.N., Doney, J.M. and Smith, W.F. 1979. Lactation pattern in Scottish Blackface and East Friesland x Scottish Blackface crossbred ewes. J. agric. Sci., Camb. 92:133-138.

Rao, M.K. and Sundaresan, D. 1979. Influence of environment and heredity on the shape of lactation curves in Sahiwal cows. J. agric. Sci., Camb. 92:393-401.

Torres-Hernandez, G. and Hohenboken, W. 1979. Genetic and environmental effects on milk production, milk composition and mastitis incidence in crossbred ewes. J. Anim. Sci. (In press).

Wilson, L.L., Varela-Alvarez, H., Hess, C.E. and Rugh, M.C. 1971. Influence of energy level, creep feeding and lactation stage on ewe milk and lamb growth characters. J. Anim. Sci. 33:686-690.

Wood, P.D.P. 1967. Algebraic model of the lactation curve in cattle. Nature, Lond. 216:164-165.

Wood, P.D.P. 1968. Factors affecting persistency of lactation in cattle. Nature, Lond. 218:894.

Wood, P.D.P. 1969. Factors affecting the shape of the lactation curve in cattle. Anim. Prod. 11:307-316.

Wood, P.D.P. 1970. A note on the repeatability of parameters of the lactation curve in cattle. Anim. Prod. 12:535-538.

Wood, P.D.P. 1976. Algebraic models of the lactation curves for milk, fat and protein production, with estimates of seasonal variation. Anim. Prod. 22:35-40.

TABLE 1. LACTATION CURVE COEFFICIENTS OF SINGLE-REARING AND TWIN-REARING EWES.

Coefficient	SR ewes	TR ewes
ℓn a	6.97 ± .15	7.10 ± .14
a (liters)	1.06	1.21
b	.318 ± .062	.299 ± .058
c	.020 ± .002	.019 ± .002

TABLE 2. DESCRIPTIVE STATISTICS OF TOTAL MILK PRODUCTION (LITERS) ESTIMATED BY THE CUMULATIVE METHOD AND BY WOOD'S MODEL

	Cumulative method	Wood's model
Mean ± s.e.	133.2 ± 3.4	144.8 ± 4.1
Standard deviation	24.8	28.7
C.V. (%)	18.6	19.8
Maximum	182.8	197.3
Minimum	82.6	85.9
Skewness	-.19[a]	-.18[a]
Kurtosis	2.32[a]	2.32[a]

[a]Not significantly different from a normal distribution.

TABLE 3. STATISTICS COMPARING PERSISTENCY OF LACTATION FOR SINGLE-REARING *VS* TWIN-REARING EWES

Method	SR ewes	TR ewes
1. S	5.133	5.116
2. $R_{2:1}$	.729	.742
3. $R_{3:1}$	.418	.439
4. $\hat{\beta}_{MP/D}(m\ell)$	-15.3	-16.5
5. $MP_{20:109}$	.259	.255

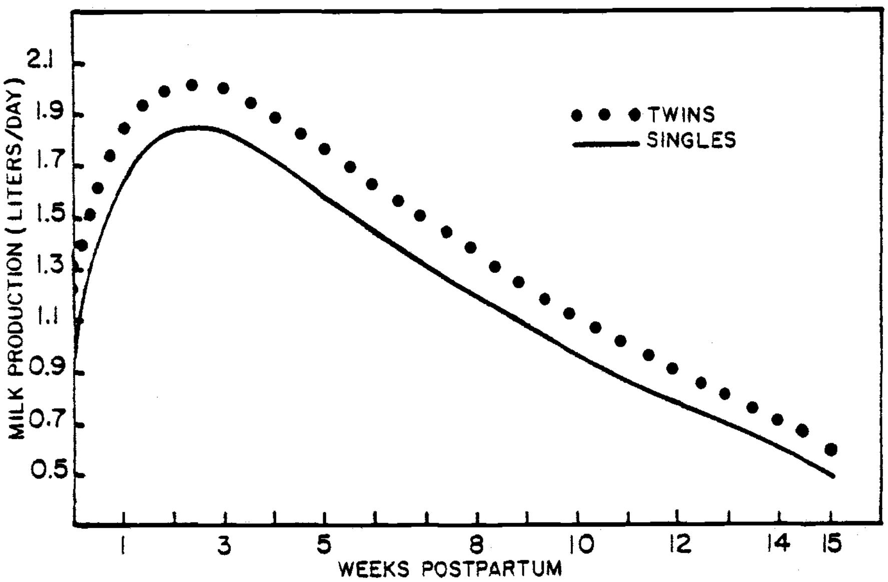

Figure 1. Lactation curves of single-rearing vs twin-rearing ewes estimated from the formula $Y(x) = ax^b e^{-cx}$.