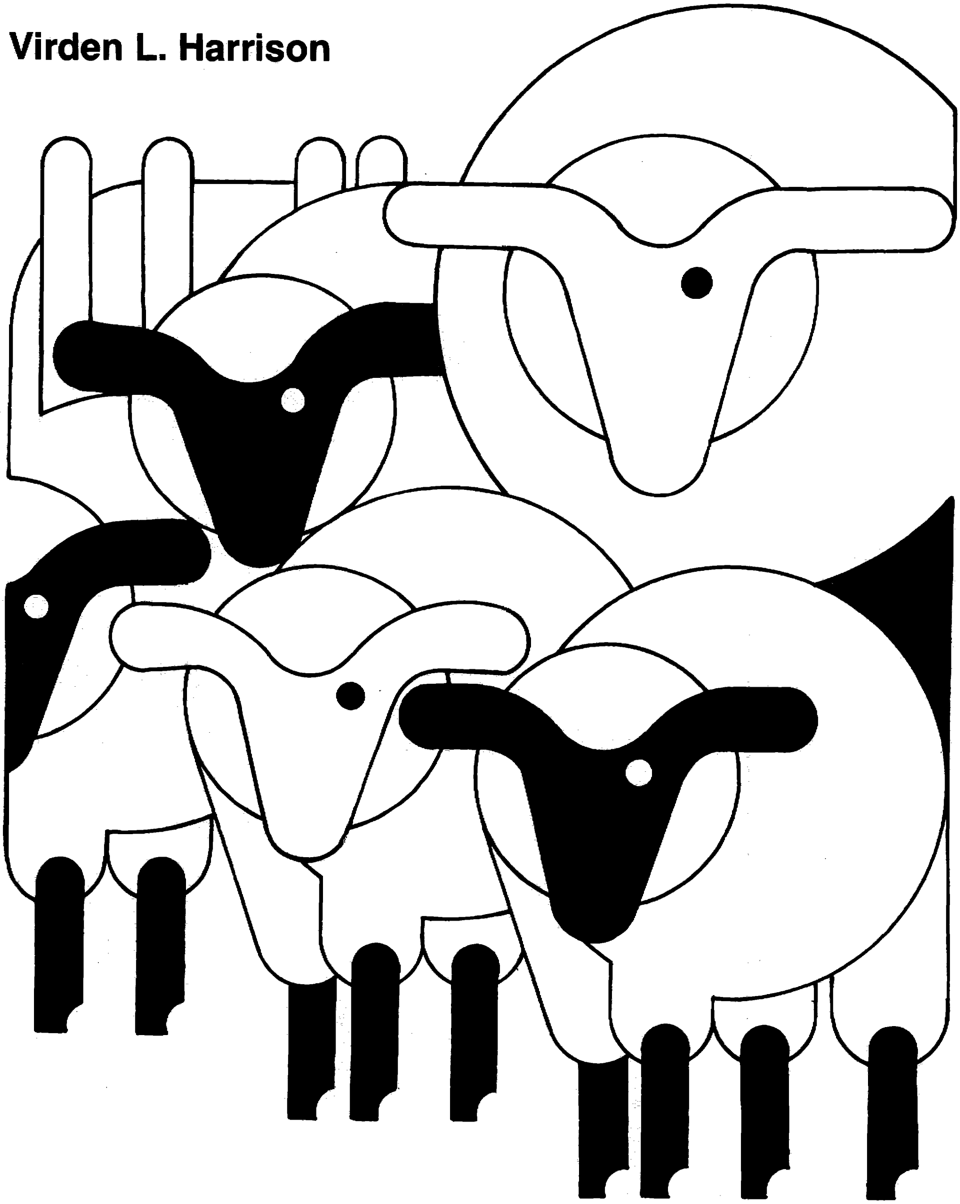
# Sheep Production: Intensive Systems, Innovative Techniques Boost Yields

**Virden L. Harrison**



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## ABSTRACT

Lamb production per ewe can be doubled or tripled through intensive management practices and by use of certain innovations. Some of these practices include selecting for ewes that produce multiple births, inducing twice-a-year lambing, breeding ewes to lamb at one year of age, formulating diets for optimal weight gain and nutrition, and controlling losses due to diseases, parasites, and predators. New technologies are described and cost and return budgets are prepared for four types of sheep systems: two intensive management types and two pasture and open range types. Intensive sheep production using the latest innovations can be profitable at lamb prices near the 1979 level of about $65 to $70 per hundredweight.

Keywords: Lamb production, sheep production, innovations, new technologies, intensive sheep production, sheep facilities.

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## SUMMARY

Improved management practices and innovations can double or triple sheep production per ewe. Some of these are: intensive selection for higher reproduction and performance traits, twice-a-year lambing, out-of-season mating, twin or triplet lambing induced by hormone treatments, artificial insemination, pregnancy checking, synchronized breeding and lambing, and hand mating.

Most of those practices require unique management skills and large investments in labor, feed, and facilities. Consequently, such practices cannot be applied to the traditional methods of raising sheep on pasture and open range with few facilities and little management. For each ewe to produce twins or triplets twice a year or thrice in 2 years requires precise scheduling, improved nutrition, an improved flock health program, and hormone or light treatments to induce out-of-season breeding (or breeds that lamb naturally more than once a year).

Both the risks and returns may be greater for an intensive system. However, current prices for lamb make it more profitable than the pasture and range systems. At $75 per hundredweight lamb prices, net returns for management after 1 year of operation of a flock of 1,000 ewes were estimated to be $48,500 for the intensively managed system compared with $9,800 for the open range system. Lower lamb prices (of $55) caused larger losses for the intensive system than for the open range system ($19,200 loss compared with a $1,200 loss, respectively).

Hormones, antibiotics, and other chemicals have been used successfully to induce out-of-season pregnancies and multiple ovulations, to synchronize breeding and lambing, to improve ram fertility, to induce or prevent lactation, to induce early puberty, to promote lamb growth, and to reduce disease. These measures require a high degree of skill and planning, as

well as a change in nutrition levels and a need to take into account the breed, age, season of year, and physical condition of the sheep.

Facilities needed for intensive production to capture most of the improved management practices and available innovations vary greatly from those used in traditional sheep production systems. Total or partial confinement facilities, together with high levels of management, are required to adopt all the available innovations.

This report presents budgets for four types of sheep enterprises, each with 1,000 ewes: total confinement, semiconfinement, range and pasture production with lambing shelter, and range and pasture production with no buildings. Total investment per ewe for all facilities, equipment, machinery, and livestock for the four systems in the order listed above is estimated at $364, $254, $119, and $84. Corresponding lamb numbers born per ewe in the flock each year are estimated to be 3.6, 2.78, 1.3, and 1.17, respectively.

# Sheep Production

## Intensive Systems, Innovative Techniques Boost Yields

Virden L. Harrison[1]

*The characteristic of science power is that production processes employ major technologies that tend to be more complementary--their combined use tends to create greater productivity than the sum of the productivities of each used in isolation (30, p. 16).* 2/

### INTRODUCTION

Earlier experiments have demonstrated that sheep production can be improved with various management techniques, such as genetic selection, and innovations, such as artificial insemination and hormone treatments. A combination of those innovative practices, however, can improve production dramatically. Applying many of the available innovations, an intensively managed sheep enterprise for a flock of 1,000 ewes is estimated to be able to produce 3,056 lambs for market per year compared with 503 lambs produced by an open range sheep enterprise--a sixfold increase.

This study describes available innovations in sheep production and demonstrates their potential for improved production and profitability of sheep enterprises. The term "innovation" in this manuscript

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2/ Underscored numbers in parentheses refer to items listed in the References at the end of this report.

includes certain practices which, though not necessarily new, have not been generally adopted by sheep producers, but which become feasible in a management system as facilities are altered to include a package of improved techniques.

Some innovations are listed below that may be appropriate to an intensively managed sheep enterprise with adequate confinement or partial confinement facilities:

Intensive selection to improve reproductive and growth traits.
Twice-a-year lambing.
Out-of-season mating.
Twin or triplet lambing through use of hormones or new breeds.
Artificial insemination.
Early weaning and lamb nurseries.
Ultrasonic pregnancy checking (using sound waves) and timely rebreeding or culling.
Ram fertility and competence testing.
Predator avoidance and control.
First-year lambing of ewes.
Synchronized breeding (inducing estrus so a flock of ewes can be bred within a 2- or 3-day period).
Inducing daytime lambing.
Hand mating (breeding ewes individually in a pen with a ram).
Parasite and disease control.

Some of those practices have been known for a long time, but most have not been adopted. Others only recently became available--such as out-of-season mating, hormonal inducement of multiple lambing, synchronized breeding and lambing, artificial insemination, and ultrasonic pregnancy checking. Few of the items listed could be used in the traditional open range production system, but may be adopted in a system where the operator has close daily observation and control. Sheep production under close confinement is not typical; few commercial enterprises practice it.

Nevertheless, sheep production under confinement conditions can be profitable if a package of innovations together with high levels of management are applied. This study shows the theoretical profitability of alternative confinement systems using applicable innovations and management practices. Budgets of four alternative sheep production systems with an analysis of their profitability are included.

## BACKGROUND

The 17 westernmost of the 48 contiguous States produce about 80 percent of the Nation's sheep. This region contains extensive public and private ranges, some of which are better suited for sheep than for cattle. In 1974, about 62 percent of ewes lambed on pasture or range with no lambing facilities (15, p. 20). About 87 percent of lambs were born during the 5-month period January through May.

Death losses in sheep and lambs experienced by 8,910 producers in 15 Western States were tabulated in a 1974 survey by the U.S. Department of Agriculture (14). 3/ Adult sheep losses from all causes were 10.4 percent in 1974 and hovered between 10 and 13 percent between 1956 and 1975.

Lamb losses, which have been increasing during the last 20 years, reached 23.2 percent of lambs born in 1974. Newborn lambs are extremely sensitive to diseases, parasites, cold, and predation. 4/ Further, a lamb born as a twin or triplet may be abandoned when its dam's attention is diverted by its littermates. Fortunately, these problems can be largely eliminated by adequate facilities and more intensive management.

Almost 60 percent of sheep producers in the Western States had fewer than 50 head of breeding ewes in 1974; 28 percent carried 50 to 300 ewes; 7 percent

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3/ The 1974 survey is the most recently published extensive survey of sheep losses.

4/ Predation in 1974 accounted for about half of all lamb losses and one-third of adult sheep losses (14).

carried 300 to 1,000 ewes; and 6 percent carried over 1,000 ewes. But 63 percent of stock sheep (those kept for breeding) were in herds of 1,000 or more. About 9 out of 10 sheep producers use sheep as a supplementary enterprise to increase their total income and to glean forage on their farms and ranches.

Few sheep producers can capture recent innovations in sheep production because of the cost of adopting the innovations, the lack of sufficient sheep numbers to cover the costs, and because few of the innovations are adaptable to the typical range sheep system. Consequently, if new sheep production technologies are to be implemented, whole new systems will have to be formulated. Until recently, sheep prices were low, giving producers little incentive to change from the traditional range-type or supplementary enterprise-type system. Since 1974, however, sheep prices have improved substantially (table 1). The incentive to expand the sheep enterprise is high at this writing and is expected to remain high.

Table 1--Prices received by farmers for meat animals

| Year | Feeder lambs (San Angelo) | Slaughter lambs (San Angelo) | Slaughter sheep (U.S.) | Feeder steers (Omaha) | Choice slaughter steers (Omaha) | Slaughter hogs (Omaha) |
|---|---|---|---|---|---|---|
| | Dollars per 100 pounds | | | | | |
| 1966 | 23.60 | 24.10 | 6.84 | 25.93 | 25.71 | 22.50 |
| 1967 | 21.50 | 23.60 | 6.35 | 25.47 | 25.29 | 18.59 |
| 1968 | 24.50 | 26.60 | 6.55 | 26.36 | 26.87 | 18.40 |
| 1969 | 27.50 | 28.50 | 8.24 | 29.77 | 29.45 | 22.92 |
| 1970 | 26.97 | 27.45 | 7.69 | 30.24 | 29.36 | 20.92 |
| 1971 | 25.86 | 27.16 | 6.58 | 32.48 | 32.39 | 17.64 |
| 1972 | 30.24 | 30.70 | 7.28 | 36.54 | 35.78 | 25.64 |
| 1973 | 37.17 | 38.20 | 12.70 | 45.82 | 44.54 | 38.86 |
| 1974 | 56.52 | 40.51 | 11.30 | 35.13 | 41.89 | 33.52 |
| 1975 | 41.40 | 44.45 | 11.20 | 36.35 | 44.61 | 47.05 |
| 1976 | 51.28 | 49.87 | 13.20 | 38.69 | 39.11 | 41.17 |
| 1977 | 55.12 | 54.28 | 13.40 | 40.85 | 40.38 | 39.60 |
| 1978 | 75.61 | 65.33 | 21.70 | 57.21 | 52.34 | 47.06 |
| 1979 1/ | 76.97 | 67.98 | 26.80 | 84.88 | 67.67 | 43.52 |

1/ Estimated.

Sources: (38, 39).

As sheep and lambs become more valuable, death losses of the order reported in 1974 become unacceptable and the incentive increases to obtain higher conception rates and more lambs per ewe per year. As discussed in the next section, most producers are a long way from reaching the potential in sheep production made possible by various innovations.

## INNOVATIONS AND THEIR POTENTIAL

### Selection for Reproductive and Performance Traits

Large differences among sheep breeds in reproductive and performance traits make possible opportunities for increasing both efficiency and quality of lamb production. Specific differences among breeds have been noted in: conception rates; semen quality; 5/ embryo mortality; weights at birth, weaning, and puberty; growth rates; percentage of twins and triplets; anestrous period; milk production; ovulation response to hormones; and adaptation of ewes and lambs to environmental stress (37). Desirable traits and performance can be increased in a flock by use of crossbreeding and breeds best adapted to environmental and market conditions, for example, the common mating of "blackface" rams selected for their growth and carcass characteristics to "whiteface" ewes which contribute adaptability to range conditions, longer breeding season, and good wool production (3). Thus, profit margins can be increased by choosing breeds and crossbreeding systems that maximize gains from both breed superiority and hybrid vigor of crossbred ewes and lambs.

Early, frequent, and high levels of reproduction are important for the success of intensive operations, but may be less important or even detrimental to operations based on seasonal range forage. For example, ewes that deliver large litters may, under range

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5/ Semen quality refers both to numbers of viable sperm and to activity of the sperm.

conditions, wean fewer lambs than ewes that give birth to one lamb per year (3). An attempt to increase the litter size stimulated a worldwide search for prolific breeds. Several have been discovered and some, notably the Finnsheep, have been extensively tested in the United States. Under good environmental conditions, Finnsheep out-produce domestic crossbred ewes by 50 live lambs per 100 ewes per year for ewes that were a cross of one-half Finnsheep and by 20 lambs per 100 ewes for ewes that were a cross of one-fourth Finnsheep (8). Such highly prolific breeds are best adapted to intensive or semi-intensive systems with high levels of management, because ewes raising twins or triplets need adequate nutrition and stress protection to keep the lamb alive.

## Twice-a-Year Lambing and Out-of-Season Mating

The gestation period of sheep is a few days short of 5 months for most breeds. The potential thus exists for two lamb crops per year. Certain exotic breeds characteristically breed and lamb twice a year: the Romanov of Russia, the Deman of Morocco, the St. Croix of the St. Croix Islands, the Peliguey of Mexico, the Barbados of Barbados, the Chios of Greece, and the Flemish of Belgium (22). In addition, some U.S. breeds have a sizeable proportion of ewes that will lamb naturally twice a year. The U.S. Sheep Experiment Station at Dubois, Idaho, reports Dorset x Targhee ewes that lambed twice a year for 3 consecutive years. Nearly all ewes can be induced to breed twice a year by applying certain management practices, such as early weaning of lambs and using hormones to induce estrus.

Most domestic ewes are anestrous in certain seasons of the year and when they are nursing their young. Table 2 shows the percentage of ewes of several breeds exhibiting estrus by month. Table 3 shows the percentage of Rambouillet ewes ovulating and detected in estrus as well as the numbers of corpora lutea (eggs released) per ewe ovulating by month. These data show very low fertility rates from April through August in Idaho and Wisconsin and from March through June in

Texas. Ram infertility follows somewhat the same pattern as ewe infertility.

To obtain two lambings per year, ewes would have to be bred within 40 days after lambing. Under most conditions, this would require weaning lambs early--at 2 to 6 weeks of age. Breeding ewes twice a year without hormone therapy will also require a breed with a long breeding season and careful selection of the time for lambing and breeding to avoid the deep anestrous period. Hulet suggested that, in Idaho, ewes could be bred in March and September to lamb in August and February. He further suggests that, because of the effect of latitude on breeding season, Texas ewes could be bred in January and July for June and December lamb-

Table 2--Percentage of ewes showing at least one estrus in a 4-week period, by month and breed, at Madison, Wis.

| Breed | Jan. | Feb. | Mar. | Apr. | May | June |
|---|---|---|---|---|---|---|
| | | | Percent | | | |
| Texas Rambouillet | 69 | 54 | 68 | 54 | 42 | 8 |
| Montana Rambouillet | 77 | 50 | 42 | 38 | 23 | 4 |
| Wisconsin Hampshire | 76 | 72 | 72 | 36 | 28 | 4 |
| Beltsville Hampshire | 64 | 64 | 60 | 28 | 8 | 0 |
| Suffolk | 71 | 75 | 71 | 13 | 33 | 4 |
| Targhee | 40 | 52 | 52 | 28 | 16 | 0 |
| Dorset | 70 | 59 | 78 | 26 | 30 | 4 |
| Columbia | 57 | 39 | 61 | 35 | 22 | 4 |
| Simple average | 65.5 | 58.1 | 63.1 | 32.3 | 25.3 | 3.5 |
| | July | Aug. | Sept. | Oct. | Nov. | Dec. |
| Texas Rambouillet | 0 | 31 | 65 | 81 | 85 | 69 |
| Montana Rambouillet | 0 | 12 | 50 | 81 | 81 | 77 |
| Wisconsin Hampshire | 0 | 0 | 72 | 96 | 96 | 80 |
| Beltsville Hampshire | 4 | 20 | 68 | 84 | 96 | 76 |
| Suffolk | 0 | 16 | 75 | 88 | 96 | 83 |
| Targhee | 0 | 4 | 80 | 88 | 92 | 68 |
| Dorset | 0 | 11 | 74 | 93 | 93 | 81 |
| Columbia | 0 | 30 | 56 | 78 | 83 | 78 |
| Simple average | 0.5 | 15.5 | 67.5 | 86.1 | 90.3 | 76.5 |

Source: (22 p. 130).

ing (22, 23). Both genetic selection and management are important to achieve success in accelerated lambing--genetic selection to extend the length of breeding season and improve fertility in the early postpartum ewe, and management for the ewes and rams to be prepared at the proper time and in the proper physical condition for breeding.

Scientists at Beltsville, Md., have developed a breed called Morlam that lambs more frequently than once a year. This breed, after 15 years of selection, breeds nearly as well at any season of year at Beltsville. Researchers at Dubois, Idaho, have developed a highly prolific new breed called Polypay which includes crosses of Dorset, Targhee, Finnsheep, and Rambouillet. Since its development in 1969, the Polypay has shown impressive out-of-season fertility rates and high prolificacy in terms of numbers of lambs born and weaned

Table 3--Effect of time of year on estrus and ovulation in Rambouillet ewes in Idaho and Texas

| Month | Percentage of ewes in estrus | | Percentage of ewes ovulating | | CL per ewe ovulating in Idaho 1/ |
|---|---|---|---|---|---|
| | Idaho | Texas | Idaho | Texas | |
| | Percent | | | | Number |
| January | 100 | 100 | 100 | 100 | 1.89 |
| February | 100 | 100 | 100 | 94 | 1.57 |
| March | 89 | 40 | 94 | 52 | 1.50 |
| April | 26 | 38 | 32 | 32 | 1.37 |
| May | 2 | 31 | 2 | 31 | 1.00 |
| June | 7 | 44 | 7 | 75 | 1.00 |
| July | 6 | 94 | 6 | 94 | 1.00 |
| August | 12 | 86 | 41 | 100 | 2/ 1.75 |
| September | 100 | 94 | 100 | 94 | 1.72 |
| October | 100 | 94 | 94 | 100 | 1.80 |
| November | 100 | 97 | 100 | 91 | 1.86 |
| December | 100 | 100 | 100 | 100 | 1.88 |

1/ CL = corpora lutea or eggs released per ovulation period.
2/ Only 16 ewes per group. As this one figure is higher than the pattern, it is likely that if more ewes were observed this figure would be nearer 1.60 than 1.75.

Source: (22, p. 121).

per year. Selection studies have begun for the Polypay to lamb twice a year without hormone therapy (22).

Thus, twice-a-year lambing is possible with current technology and good management, but the success rate is still low. Table 4 shows the level of success for four breeds of ewes given two opportunities to lamb per year as compared to three breeds given one opportunity. Fertility rates were high in the fall breeding period but low in the spring, even with hormone therapy. The highest performing breed (Polypay) had a 5-year (1972-76) average spring pregnancy rate of only 38 percent (20, p. 3).

## Use of Hormones, Antibiotics, and Other Chemicals

Chemicals have been used with varying degrees of success to alter the natural bodily functions of sheep

Table 4--Lamb production by breed at the U.S. Sheep Experiment Station (Dubois, Idaho) under herded and fenced range conditions (2-year average, 1975-76)

| Breed and management | Ewes in flock 1/ | Ewes lambing 2/ | Lambs born 2/ | Lambs born alive 2/ | Lambs weaned 2/ | Weight of lambs weaned at 120 days of age 2/ |
|---|---|---|---|---|---|---|
| | Number | - - - | Percent | - - - | | Pounds |
| Columbia (Reg.) | 539 | 85 | 123 | 109 | 78 | 59.0 |
| Targhee (Reg.) | 642 | 88 | 135 | 122 | 99 | 74.2 |
| Rambouillet (Reg.) | 645 | 90 | 130 | 118 | 95 | 67.4 |
| Targhee (ML) | 151 | 3/ 107 | 181 | 161 | 124 | 86.0 |
| Dorset x Targhee (ML) | 175 | 112 | 182 | 162 | 129 | 92.6 |
| Polypay (ML) | 181 | 124 | 211 | 191 | 154 | 103.2 |
| Finnsheep x Rambouillet (ML) | 184 | 114 | 244 | 219 | 162 | 101.4 |

Reg. = Regular flock ewes with once per year breeding, and managed under herded range conditions. ML = All ewes given two opportunities to breed per year, and managed under fenced range conditions; hormones were used in the spring (April and May) following lambing.

1/ Ewes 2 years old and over.
2/ Per ewe in the flock, per year.
3/ Figures over 100 in this column indicate that some ewes lambed twice per year.

Note: Vibriosis, a contagious bacterial infection, in the spring of 1975 reduced the lamb crop.

Source: (22, p. 127).

and other animals. Treatments designed to improve or complement management of sheep may use chemicals to:

- Induce estrus to enhance out-of-season pregnancies.
- Induce multiple ovulations.
- Synchronize breeding and lambing.
- Induce daytime or early parturition.
- Improve ram fertility.
- Induce or prevent lactation.
- Induce early puberty.
- Promote growth and reduce diseases by feeding antibiotics.

Each of these items may be useful in an intensively managed sheep operation as discussed below.

## Inducing Estrus

Reasons to induce estrus include promoting out-of-season matings, promoting twice-a-year lambings, synchronizing the breeding and lambing of a flock of ewes, and inducing multiple ovulations. The most common technique for inducing estrus in the ewe is to insert into the vagina a sponge impregnated with a progestogen and to leave it there for 8 to 14 days. When the sponge is removed, the ewe is given an intramuscular injection of pregnant mares serum gonadotrophin (PMSG). Then, about 48 hours after the PMSG injection, a ram is introduced to the ewe.

Pregnancy rates depend on several factors, including breed, age, season of the year, diet, physical conditions of the ewe and ram, and whether the ewes are nursing lambs. Table 5 shows the lambing outcome for three seasons of the year for 25,653 ewes treated with progestogen and PMSG from 1968-75 (17). Ewes treated in summer and autumn had higher conception rates and larger litters than spring-treated ewes. Concerning the effect of breed, Laster and Glimp (25) reported that significantly higher percentages of Finnsheep-cross, Coarse Wool, Dorset, and Rambouillet ewes lambed than did Targhee, Suffolk, Corriedale, and Hampshire ewes when treated with progestogen-PMSG during anestrus (table 6).

Ewes were given three opportunities to breed in 2 years in studies on the effect of hormone therapy (progestogen-PMSG) conducted at Colby, Kans. Schwulst and Banbury (31) reported that hormone therapy consistently increased lambing and lamb crop percentages per year (table 7). Within breed groups, the yearly lamb crop per ewe of treated over nontreated ewes was 1.84 vs. 1.53 for Texas ewes, 2.14 vs. 1.91 for Dorset x Texas crosses, and 1.84 vs. 1.63 for Hampshire x Texas crosses.

Christenson reported experiments involving anestrous ewes treated with progestogen-PMSG to induce estrus (6). Ewes were closely synchronized in their estrous periods as a result of the hormone treatments. The 165 hormone-treated ewes had substantially higher estrous response (96 vs. 23 percent) and lambing rates (63 vs. 5 percent) than 91 untreated ewes. PMSG was injected twice--the day after progestogen removal and 15 days later. Eighty-two ewes (50 percent) exposed to rams were bred only after the first PMSG injection and 58 percent of those lambed. From the 104 treated ewes that lambed, 193 lambs were born giving 1.86 lambs per ewe lambing. Seven lambs were born to five control ewes. Lamb survival to weaning (40 days postpartum) for both the control and treated ewes averaged 83 percent.

Table 5--Lambing outcome in response to standard progestogen-PMSG treatment applied in 1968-75, Dublin, Ireland

| Item | Unit | Spring | Summer | Autumn |
|---|---|---|---|---|
| Groups of ewes | Number | 83 | 594 | 41 |
| Ewes treated | do. | 2,508 | 21,545 | 1,600 |
| In estrus | Percent | 93.00 | 97.00 | 97.20 |
| Conceptions | do. | 37.00 | 66.00 | 77.60 |
| Ewes lambing | Number | 871 | 13,795 | 1,206 |
| Ewes lambing | Percent | 34.70 | 64.00 | 75.40 |
| Lambs born | Number | 1,375 | 22,396 | 2,088 |
| Lambs born per ewe treated | do. | 0.55 | 1.04 | 1.31 |
| Lambs born per ewe lambing | do. | 1.58 | 1.62 | 1.73 |
| Ewes pregnant after first estrus | Percent | 34.70 | 64.00 | 75.40 |
| Ewes pregnant after first and second estrus | do. | 35.00 | 79.60 | 90.50 |

Source: (17, p. 19).

Table 6--Ovulation rate and lambing performance of anestrous ewes treated with progestogens and PMSG (Clay Center, Nebr.) 1/

| Breed | Number of ewes | | | Ovulation rate 2/ | | Ewes lambing | | | Lambs born per ewe exposed | | | Lambs born per ewe lambing | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | B | C | A | B | C | A | B | C | A | B | C |
| | Number | | | | | Percent | | | Number | | | | | |
| Hampshire | 74 | 65 | 59 | 1.3 | 2.0 | 0 | 6 | 10 | 0 | 0.12 | 0.36 | 0 | 2.00 | 1.17 |
| Corriedale | 18 | 16 | 14 | 1.3 | 2.4 | 0 | 19 | 14 | 0 | .19 | .14 | 0 | 1.00 | 1.00 |
| Suffolk | 49 | 34 | 28 | 1.6 | 1.3 | 0 | 3 | 14 | 0 | .03 | .21 | 0 | 1.00 | 1.33 |
| Targhee | 29 | 23 | 22 | 1.4 | 4.8 | 7 | 26 | 23 | 0.07 | .48 | .36 | 1 | 1.83 | 1.60 |
| Rambouillet | 69 | 55 | 58 | 2.2 | 4.5 | 2 | 20 | 31 | .01 | .32 | .50 | 1 | 1.64 | 1.61 |
| Dorset | 27 | 21 | 20 | 2.2 | 1.3 | 4 | 24 | 45 | .04 | .29 | .81 | 1 | 1.20 | 1.80 |
| Coarse Wool | 26 | 19 | 16 | 1.8 | 2.3 | 0 | 32 | 50 | 0 | .37 | .69 | 0 | 1.17 | 1.38 |
| Finnsheep cross | 26 | 15 | 16 | 3.3 | 2.7 | 0 | 47 | 56 | 0 | .93 | .88 | 0 | 2.00 | 1.56 |
| Weighted mean | 318 | 248 | 233 | 1.9 | 2.6 | 2 | 22 | 30 | .02 | .34 | .49 | 1 | 1.48 | 1.43 |

A = Control ewes; received no hormones.
B = Ewes treated with progesterone and 750 International Units of PMSG.
C = Ewes treated with progesterone and 1,000 Units of PMSG.

1/ PMSG = Pregnant mares serum gonadotrophin.
2/ Number of eggs released based on surgical section of seven ewes per subgroup performed 8 to 13 days after ewes were bred by rams.

Source: (25, p. 1,133).

In the same experiment, Christenson demonstrated that early weaning and short treatment with hormones can be successful in moving toward a system of two lamb crops per year. The following tabulation shows the results of varying the length of progestogen treatment (8 vs. 16 days) and the interval between parturition and initiation of treatment (38 vs. 73 days):

| Days between parturition and hormone treatment | Days of progestogen treatment | | Average |
|---|---|---|---|
| | 8 | 16 | |
| | Percentage of ewes lambing | | |
| 38 | 68 | 51 | 60 |
| 73 | 60 | 72 | 66 |
| Average | 64 | 62 | 63 |

## Inducing Multiple Ovulations

The number of eggs released in ewes can be increased (with an accompanying increase in the number of lambs produced per ewe) by the use of hormones, mainly PMSG (6, 25, 31). Breeds that have a higher natural ovulation rate also have a higher ovulation response to PMSG. For example, the ovulation rate for adult Finnish Landrace ewes increased from a normal

Table 7--Effects of hormone therapy on lamb production at Colby, Kans. 1/

| Item | Unit | Dorset X Texas | | Hampshire X Texas | | Texas | |
|---|---|---|---|---|---|---|---|
| | | Control | Treated | Control | Treated | Control | Treated |
| Ewes exposed | No. | 301 | 302 | 301 | 288 | 269 | 258 |
| Ewes lambing | do. | 270 | 278 | 246 | 239 | 216 | 217 |
| Ewes lambing | Pct. | 89.7 | 92.1 | 81.7 | 83.0 | 80.3 | 84.1 |
| Lambs born | No. | 383 | 430 | 326 | 353 | 274 | 316 |
| Lambs/ewe exposed/crop | do. | 1.27 | 1.42 | 1.08 | 1.23 | 1.02 | 1.23 |
| Lambs/ewe lambing/crop | do. | 1.42 | 1.55 | 1.33 | 1.48 | 1.27 | 1.46 |
| Lambs/ewe exposed/year | do. | 1.91 | 2.14 | 1.63 | 1.84 | 1.53 | 1.84 |

1/ 4-year average for six lamb crops.

Sources: (31 and 37, p. 125).

3.31 corpora lutea per ewe to 12.2 for PMSG-treated ewes in a study involving seven breeds of sheep treated in the normal breeding season in Scotland by Bradford et al. (4). Other experiments, however, have shown no increase in the number of lambs weaned per ewe as a result of superovulation with hormone treatment.

The following problems have been noted with induced superovulation: (1) inhibition of sperm movement toward the uterus resulting in reduced conception rates; (2) higher embryonic mortality; (3) premature births, with weak, small lambs, that are less resistant to disease, and therefore more deaths; (4) increased nutritional needs for ewes carrying multiple lambs; (5) increased probability of abandonment of one or more lambs by the ewe; (6) possibility that ewes may not have enough milk to support more than one or two lambs; and (7) increased management, facilities, and labor required for early weaning, special nutrition, and nurseries. A high degree of success in inducing multiple ovulations has been assured through research, but the overall success of impregnating the ewes, bringing them to term, and weaning the lambs will depend on solving the above problems by paying attention to breed characteristics, physiology, nutrition, health care, and management.

## Inducing Daytime or Early Parturition

If desired, a flock of ewes can be lambed on the weekend and mostly during daylight hours. Ewes that were bred in synchronism can also be induced to lamb in synchronism over a 2-day period by being injected with corticosteroids, estrogens, or prostaglandins (1, 2, 18, 27, and 34). Bosc et al., for example, reported that mean parturition time for two breeds was about 30 hours after injection of estradiol benzoate; 80 to 95 percent of ewes lambed within 48 hours and 70 to 75 percent lambed during daytime if the injection was given at 8 a.m. (2, p. 94). Survival and growth rates of lambs with induced delivery was as good as or better than lambs from untreated ewes. However, the treatment should be given within a few days of the natural parturition date to avoid excessive mortality and difficult births.

Inducing parturition in the ewe can thus be beneficial from several points of view:

- The gestation period of ewes in a twice-a-year lambing regime can be shortened a few days to permit use of a 6-month lambing cycle.
- An entire flock of ewes can lamb within a few days' time, thus shortening the intense observation period and facilitating tight scheduling of lambing pens.
- Most of the ewes can be lambed during the normal daylight work schedule thus reducing the night crew requirement.
- A flock of ewes can retain their synchronism in their lambing, weaning, and rebreeding cycle.

## Inducing Early Puberty

Some breeds of lambs naturally mature early and respond to improved diets to increase their growth rate and body size early in life; such breeds do not need hormones to induce early puberty in ewe lambs. The Rambouillet and other breeds that mature slowly, however, may require hormone treatments to induce lambing at 1 year of age. (This topic is further discussed in a later section on first-year lambing.)

Puberty in ewe lambs can be accelerated by the use of hormones, according to Foote and Matthews (12). Since the prepubertal ewe is anestrous, treatment with estradiol, progestogen, and PMSG in the same manner (though at different levels) as for induction of estrus in the mature ewe (described earlier) can hasten puberty and increase the percentage of ewes lambing at 1 year of age.

## Promoting Growth and Reducing Diseases

Extensive research has been conducted on the use of low levels of antibiotics in animal feeds. The antibiotics generally increase the rates of weight gain and reduce incidences of certain diseases. Though the physiological response of feeding low levels of antibiotics is not well understood, three types of responses have been hypothesized (42): (1) a metabolic effect, whereby the antibiotic directly affects the metabolic process of the animal; (2) a nutrient sparing effect, in which the antibiotic stimulates the animal's naturally occurring microorganisms to synthesize certain amino acids and other nutrients; and (3) a disease-control effect, whereby antibiotics suppress harmful organisms that cause disease. The disease-control effect is considered to be the most important of the three.

In sheep, the antibiotics chlortetracycline (aureomycin) and oxytetracycline (terramycin) are beneficial as supplements to lamb diets in promoting weight gains and feed efficiency. Increased growth rates of 20 percent or more have been obtained by feeding antibiotics to feedlot lambs. Antibiotics are most effective when added to high-roughage rations. The antibiotics offer some protection against low-level disease infections and also combat enterotoxemia, a bacterial disease. Antibiotic supplements are recommended as soon as the lamb begins to eat dry feed, that is, in the creep feeder.

Another feed additive proven effective in increasing feed efficiency is monensin, which, though classed as an antibiotic, has only limited antibiotic activity--its main effect is to alter the metabolic products of microbes in the rumen. Animals do not gain weight faster due to monensin; they gain at the same rate but with less feed. Developed as a treatment for coccidiosis (an intestinal disease) in poultry and livestock, monensin was found effective for increasing feed efficiency as well as preventing the disease. Monensin feeding in experimental breeding stock trials hastened the onset of puberty and reduced the interval between parturition and rebreeding in ruminants, without adversely affecting the dam's weight or condition, nor the offspring's birthweight, vigor, or growth rate. Any well-managed sheep enterprise should include the use of antibiotics in the feed rations.

## SPECIAL MANAGEMENT PRACTICES

In this section, certain management practices are discussed that are important in successful sheep production, particularly in systems involving the use of innovations discussed above. A package of improved management techniques and innovations could be adopted at the same time to improve the chances of success in sheep operations.

### First-Year Lambing by Replacement Ewes

Lifetime lamb production of the ewe can be increased by breeding ewes to lamb when they are about 1 year of age (5, 11, 21, 22). Other advantages of first-year lambing include reduced maintenance costs before the start of production, shortened generation interval resulting in more rapid genetic gains from selection, and the marketing of culled, nonpregnant lambs at market lamb prices rather than at cull ewe prices. Factors influencing the fertility of 7- to 8-month-old ewe lambs are size and condition at breeding time, breed, season of birth, time of year bred, and whether or not the lamb was genetically selected for early lambing. Lambs have high pregnancy rates once they have reached about 65 percent of mature bodyweight (22, p. 119).

Table 8 shows the effects of feed, breed, and year on fertility of ewe lambs. Lambs were bred in November and December at 7 to 8 months of age. Finnsheep and Polypay breeds had high pregnancy rates, Targhee and Dorset had moderate, and Rambouillet ewe lambs had low pregnancy rates. Table 9 shows the results of a first-year lambing experiment conducted at Clay Center, Nebr., involving 565 ewes of 19 breeds and breed crosses. Crossbred ewes, especially those involving Finnsheep, were far superior to straightbreds in their ability to lamb at a year of age and in the numbers of lambs they weaned. The ewe lambs averaged 88 pounds at the beginning of the 33-day breeding period (Nov. 9 to Dec. 12, 1970) and lambed at 380 days of age. About 71 percent of all ewes lambed, and of those lambing, 1.26 lambs were born and 0.91 lambs were weaned per ewe. For the Finnsheep crosses 88 percent lambed and of those lambing, 1.54 lambs were born and 1.26 lambs were weaned per ewe.

In addition to the favorable heterotic effect (improvement due to crossbreeding) shown above, early puberty has a moderate heritability, that is, it can be improved by selection. At Dubois, Idaho, a group of Targhee ewes selected for early puberty for 8 years was compared with another similar group not selected for this trait. Ewes and lambs in the two groups were managed the same and lambs were kept together in one flock after weaning. Young lambs were exposed to rams for 45 days; 50 percent of the selected Targhees, but only 20 percent of the unselected ones, conceived (22, p. 119).

Another study at Clay Center, Nebr., involving 825 spring ewe lambs found that lambs born in litters of two or three weighed about 7 pounds less at puberty

Table 8--Fertility of 7- and 8-month-old ewe lambs, by breed, feeding regimen, and year

| Breed | 1969 1/ | 1970 2/ | 1971 3/ | 1972 4/ | 1973 5/ | 1969-73 |
|---|---|---|---|---|---|---|
| | | | Percent pregnant 6/ | | | |
| Rambouillet | 61 (31) | 17 (18) | 4 (27) | 16 (38) | 37 (30) | 27 (144) |
| Targhee | 76 (33) | 52 (27) | 10 (31) | 57 (35) | 73 (37) | 55 (163) |
| Dorset | 88 (57) | 92 (26) | 35 (20) | 64 (39) | 86 (42) | 77 (184) |
| Polypay | NA | 100 (6) | 77 (35) | 94 (65) | 97 (33) | 91 (139) |
| Finnsheep | 100 (11) | 100 (66) | 92 (39) | 94 (32) | 87 (31) | 95 (179) |

NA = Experimental data not available.
1/ Fed and bred in drylot with ewe lambs only. Half were fed 1.5 kg alfalfa pellets/head/day; others were self-fed.
2/ All were fed 0.79 kg alfalfa pellets as a supplement to dry fall range and bred on range with mature ewes.
3/ Same as for 1970 except that heavy snow and blizzard conditions existed near end of breeding. Bred on range with mature ewes.
4/ Half were fed same as for 1970. Half were fed 1.5 kg alfalfa pellets/head/day. Half were bred with mature ewes; half were bred with ewe lambs only.
5/ Same as for 1970, but very few were bred with mature ewes.
6/ Numbers in parentheses are numbers of ewes exposed to rams.

Sources: (21 and 22, p. 120).

than single births of the same breed and reached puberty 1 week later (9). Higher growth rates definitely hastened puberty. Crossbred lambs reached puberty at earlier ages and lighter weights than purebreds. Finnsheep crosses reached puberty 19 days earlier and 9 pounds lighter than Rambouillet crosses and 26 days earlier and 11 pounds lighter than purebreds.

## Predator Control and Avoidance

One-third of the sheep deaths and half of the lamb deaths reported in a survey were attributed to predators, mainly coyotes (14). The percentages of

Table 9--Characteristics of ewes lambing at 1 year of age, by breed 1/

| Breed group | Number of ewes | Breeding weight | Percent lambing of ewes exposed | Lambs born per ewe lambing | Lambs weaned per ewe lambing | Lambing difficulty score 2/ | Lamb vigor score 3/ | Average lamb birth weight |
|---|---|---|---|---|---|---|---|---|
| | Number | Pounds | - - - | Percent- | - - | Score | | Pounds |
| Suffolk | 53 | 97 | 59 | 122 | 57 | 1.3 | 1.5 | 6.6 |
| Hampshire | 93 | 86 | 55 | 101 | 43 | 1.4 | 1.6 | 7.2 |
| Rambouillet (R) | 43 | 89 | 31 | 100 | 80 | 1.6 | 1.6 | 9.3 |
| Dorset | 36 | 74 | 56 | 99 | 58 | 1.2 | 1.4 | 6.4 |
| Targhee | 51 | 88 | 38 | 116 | 77 | 1.2 | 1.2 | 8.0 |
| Corriedale | 28 | 84 | 33 | 111 | 49 | 1.4 | 1.4 | 8.0 |
| Coarse Wool | 55 | 89 | 80 | 104 | 73 | 1.2 | 1.2 | 7.8 |
| R x Dorset | 15 | 86 | 92 | 107 | 89 | 1.6 | 1.0 | 9.3 |
| R x Targhee | 12 | 94 | 51 | 100 | 42 | 1.1 | 1.6 | 8.7 |
| R x Corriedale | 18 | 90 | 62 | 101 | 79 | 1.2 | 1.1 | 8.9 |
| R x Coarse Wool | 13 | 94 | 87 | 101 | 70 | 1.1 | 1.1 | 9.1 |
| Finn x Rambouillet | 23 | 90 | 83 | 142 | 118 | 1.1 | 1.1 | 7.0 |
| Finn x Dorset | 17 | 87 | 74 | 184 | 149 | 1.0 | 1.3 | 6.3 |
| Finn x Targhee | 35 | 86 | 95 | 157 | 126 | 1.2 | 1.2 | 6.8 |
| Finn x Corriedale | 12 | 83 | 90 | 136 | 112 | 1.1 | 1.0 | 6.9 |
| Finn x Coarse Wool | 22 | 88 | 78 | 166 | 122 | 1.1 | 1.0 | 5.8 |
| Finn x Fine Wool | 7 | 87 | 100 | 172 | 138 | 1.0 | 1.0 | 5.7 |
| Finn x Columbia | 17 | 85 | 90 | 134 | 131 | 1.1 | 1.1 | 7.1 |
| Finn x Navajo | 15 | 81 | 100 | 147 | 124 | 1.1 | 1.0 | 5.7 |
| Total or average | 565 | 88 | 71 | 126 | 91 | 1.2 | 1.2 | 7.4 |

1/ Least-squares means adjusted for linear and quadratic partial regressions on age of ewe at beginning of breeding period.
2/ Lambing difficulty scores ranged from 1 to 4 where 1 = no difficulty and 4 = lamb or ewe died due to difficult birth.
3/ Lamb vigor scores ranged from 1 to 4 where 1 = no assistance required for nursing and 4 = lamb died within 2 days after birth.

Source: (26).

lamb losses to predators in 1974 in States reporting greater than 10 percent losses were as follows:

| State | Lambs lost to predators as a percentage of lambs born |
|---|---|
| Nevada | 30.4 |
| Arizona | 20.9 |
| Montana | 17.5 |
| New Mexico | 17.1 |
| Colorado | 16.5 |
| Utah | 12.9 |
| Texas | 11.8 |
| Wyoming | 11.7 |
| California | 10.7 |

Predation has been a major factor in the decisions of large numbers of producers to discontinue raising sheep (16).

Predator loss of sheep and lambs can be reduced by: getting rid of the predators; constructing coyote-proof fences; keeping a closer observation day and night; using dogs trained to kill predators; and using confinement or semiconfinement facilities. These measures are costly and involve large amounts of labor.

Attempts to destroy the predators have met with considerable opposition from environmentalists and Government agencies. Restrictions on poisons and types of control devices have left the control of predators to Government trappers, aerial gunners, and the sheep producers' rifles.

Effective coyote-proof fences are available and offer some protection to sheep. The fences are expensive to purchase and construct and thus are not economical on large pastures or public ranges.

Producing and rearing sheep in confinement or semiconfinement with intensive management can largely avoid the predator problem. Confinement facilities may thus offer an effective alternative for producers plagued by predators but who wish to remain in the sheep business. To justify the large capital investment in additional facilities, the producer may need to increase the productivity of the sheep enterprise by adopting some of the innovations and practices mentioned elsewhere in this report.

## Disease and Parasite Control

A major barrier to entry into the livestock production business is the perceived risk of rapid loss of a herd through diseases and parasites. Sheep, like other livestock species, are extremely vulnerable to numerous harmful organisms. Many of them take their toll before effective treatment can begin; for others no treatment is effective. One of the disadvantages of intensive or closely confined sheep production is the more rapid spread of pathogenic organisms through a flock. And some organisms, rarely bothersome in a range situation, may cause heavy losses in a confinement facility. Yet, close observation and immediate treatment that can occur in an intensive sheep production facility can control and sometimes eradicate some diseases and parasites.

Disease organisms and parasites are almost always present, regardless of the management system employed, and harmful organisms are usually present in the body of the sheep at all times. The amount of damage they cause depends on their numbers and activity, which in turn depend on such factors as the animal's physical condition, nutritional regime, environmental conditions, and stress.

For example, enterotoxemia, an infectious but noncontagious disease mostly affecting feedlot lambs, is caused by bacteria commonly found in soil and manure. This disease caused more economic loss among lambs fattening on pasture or in the feedlot than all other diseases combined, until a vaccine was discovered and commercially produced; the disease still kills about one-half of 1 percent of feedlot lambs. It is also called "overeating disease," which appropriately describes a common circumstance under which the disease occurs. The bacteria reside for long periods in soil and manure and because of continuous intake and excretion from sheep, the bacteria concentrate around feedlots, corrals, bedgrounds, and watering facilities. Normally, the organism multiplies slowly while traveling through the alimentary tract, forms small amounts of toxin, but is expelled in the feces before high concentrations can accumulate. But when excessive amounts of grain are consumed, some granules of starch pass to the small intestine where the bacteria, acting on the starch substrate, rapidly multiply, producing large amounts of toxins that cause sudden and unexpected death. The prevention of enterotoxemia includes a vaccination at time of entry in the feedlot, careful control of the diet so that grain concentration increases only gradually, and management to prevent overeating (24).

Parasites of many species inhabit the digestive tract, circulation system, muscle tissue, and other organs of the body. Clinical parasitism depends not only upon the number and activity of the parasites, but also upon the age, resistance, and nutritional status of the host, climatic conditions, and management practices. Economic losses due to parasitism result from unthriftiness (lack of vigor), depressed growth rates, less wool, and more deaths, as well as from the costs of preventive and control programs.

The larval stages of many parasites do more harm than adult worms. Many treatments remove only adult parasites, but if administered at the proper times, may reduce the degree of pasture contamination by larvae of the worms. Pasture rotation is a sound management practice that increases forage production as well as the nutritional level of sheep and cattle, but is not essential for successful control. Adequate sanitation practices, as well as frequent diagnosis and treatment, are essential to successful control of parasites (35, pp. 697-807; 24, pp. 87-94).

At least 10 major parasites inhabit the gastrointestinal tract of sheep and affect all ages. In Eastern, Southern, and Midwestern States, where rainfall is high, heavy concentrations of larvae accumulate in pastures and infect grazing sheep (24, p. 87). Other parasites, such as liver flukes and lungworms, cause considerable damage in sheep unless properly identified and controlled. Fortunately, chemicals are available for treatment and prevention of most parasitic diseases in sheep.

## Diet-Related Problems

In addition to disease organisms and parasites causing weaknesses and bodily malfunctions, sheep may suffer from other diet-related abnormalities including poisonous plants, imbalances in energy and protein intake, and excessive or inadequate levels of minerals and vitamins.

Range sheep are exposed to a wide variety of poisonous plants which may be highly toxic during certain stages of their growth if ingested in sufficient quantities. Sheep will generally avoid most poisonous plants or will consume nontoxic amounts unless they are unable to obtain sufficient quantities of other forage. The possibility of poisoning can be reduced by eradicating harmful species, by controlling grazing to avoid excessive consumption during the plant's toxic stages, by using pastures with controlled species, and by feeding harvested feeds in a semiconfinement system.

Insufficient energy probably limits performance of sheep more than any other nutritional deficiency and may be caused by inadequate amounts of feed or from feed of low quality (29, p. 2). Poorly digestible, low-quality forage also leads to reduced feed intake. Sheep on forage that is high in water content, such as lush, rapidly growing grasses, may be unable to consume enough energy to meet their requirements. Severe energy deficiency may cause loss of weight, reduced fertility, low milk production, reduced wool quality and quantity, and lowered resistance to infection by diseases and internal parasites. Energy requirements of sheep depend on their sex, size, age, pregnancy or lactation status, and growth, as well as on environment, shearing, and level of stress. Energy and other nutrient requirements of sheep have been published by the National Research Council (29).

Protein intake is important for normal muscular and tissue growth. Insufficient amounts of high-quality protein will reduce appetite, retard growth, lower feed efficiency, inhibit reproduction, and exacerbate digestive disturbances. Though ruminants form or synthesize amino acids, their synthesis does not supply all the amino acids in the quantity and quality needed for maximal production. High-quality protein from concentrates or urea is recommended, especially for fattening lambs.

Fifteen minerals have been demonstrated to be essential for sheep. In some soils mineral deficiencies exist; for example, areas where calcium supplementation has been found necessary include Florida, Louisiana, Nebraska, Virginia, and West Virginia. Mineral supplementation is recommended in almost all areas of the Nation. The type and amount should be based on the location, types of feed, and the characteristics of the livestock being fed. Other minerals, such as fluorine, are toxic to sheep. Vitamin supplementation is also required in certain production situations. For example, lambs housed indoors for long periods may need vitamin D supplementation unless their feed includes sun-cured hay or other feeds high in vitamin D.

Ration formulation to include a proper mix of nutrients is an essential management tool for successful sheep production. Diets have been formulated for many production situations and should be oriented to the location, types of feeds available, stage of the sheep production cycle, management objectives of the producer, and the relative costs of ration ingredients.

## Ration Optimization

After the nutrient requirements have been determined for sheep of each age group and growth or production status, it is important to select the mix of forages, grains, and protein supplements that will maximize the value of product per unit of cost. Optimal rations for each type and production stage of livestock depend on availability and costs of pastures, forages, and grains. The ration mix must be reformulated when relative prices of grains and forages change, in order to continue optimal production. For example, if corn becomes cheap relative to barley, then the composition of the ration should shift toward corn; or if hay price is reduced relative to grains, then the ration should include more hay, taking into account the desired growth rate of the lambs. Some university extension departments and some consulting firms have computer programs to formulate least-cost rations, given ingredient availabilities and prices and required levels of energy, protein, minerals, and vitamins. Nutrient composition of various feeds, methodology for formulating diets, and nutrient requirements are published in (29).

## Other Practices

Four additional management practices appropriate to intensive sheep production systems include hand mating, ram fertility and competence testing, artificial insemination, and ultrasonic pregnancy checking.

Hand mating refers to observing the successful mating of ewes with rams and then removing the ewe as soon as it has mated. The mating may be done one-on-one or in a small group of ewes and rams. The benefits include precise control and knowledge of time of breeding, the sire, and the assurance that insemination has occurred. This practice is especially useful in breeding a large number of ewes, whose estrous periods have been induced and synchronized, with a limited number of rams. It involves intense observation and management, but improved conception rates can be expected.

Ram fertility and vigor can be checked before its use in breeding. Rams vary greatly in their semen quality (viable sperm numbers and motility), vigor in seeking out ovulating ewes, success in inseminating the ewe, and number of ewes that can be serviced in a given time period. These characteristics also vary with season of the year and temperature/humidity conditions. Ram testing is especially important when breeding for high-quality offspring and when using artificial insemination. Sperm analysis is done under a microscope.

Sexual aggressiveness of the ram is determined by observing its activity with sexually receptive ewes.

Artificial insemination in sheep can be a very successful practice under intensive management systems. It is especially useful when combined with estrus inducements and synchronization--a large number of ewes can be bred to a single ram in a short time period. The semen collection, dilution, and storage, and artificial insemination procedures have been worked out and are used extensively at certain research institutions and a few commercial sheep operations. Semen from rams can be used in artificial insemination immediately after collection, within a few hours, or it can be stored in a frozen state for several years. In a range-type system a ram is used for each 20 to 30 ewes; in a hand mating system the ratio can be one ram for 50 to 100 ewes; but each ram can be used for breeding up to 500 ewes through artificial insemination (37, pp. 31-40).

Being able to determine whether or not a ewe is pregnant is an important economic consideration because nonpregnant ewes can either be rebred or culled for marketing in a timely manner. Two methods in particular have been developed to check a ewe's pregnancy. In the first, a blood sample from the ewe is analyzed for certain hormones, the level of which indicates pregnancy (37, pp. 79-88). In the second, sound waves from ultrasonic testing devices (available on the market) are beamed at the fetal area of the ewe. The sound waves penetrate soft tissue differently than the denser fetal tissue, triggering a signal on the device. The ultrasonic device can determine pregnancy after about 3 weeks following mating.

## SHEEP FACILITIES AND THEIR PRODUCTIVE POTENTIAL

Sheep can adapt to a wide range of temperature and climatic fluctuations. They can endure severely cold temperatures, as long as they are kept dry and protected from the full force of the wind. Most lambs, however, will die unless they are kept warm and dry soon after birth. Lambs have a better chance of surviving if the ewe and lamb are isolated together in a small pen for 8 to 24 hours during and immediately after lambing. Consequently, unless lambs are born during warm weather, producers must provide lambing facilities to reduce death losses and, if necessary, assist the ewes in the delivery.

Under range conditions, sheep may use buildings only once a year--at lambing time. With extremely mild conditions, ewes may lamb on the range with no buildings. Under such conditions, observation of the ewe and lamb may be low and lamb mortality may be extremely high. While successful sheep enterprises operate with minimum facilities, many of the improved management practices discussed in this report cannot be used under such conditions. Sheep are sensitive animals and will respond to improved management. For example, the diet of the ewe is important for high conception rates, successful pregnancy, and vigor of the lamb at birth. Achieving high rates of reproduction may require facilities for diet supplementation. Furthermore, some new technologies in lamb production, discussed in previous sections, can be adopted if certain facilities and equipment are provided.

Table 10 lists the technologies and improved management practices that can be carried out in four types of sheep facilities--(1) total confinement; (2) semiconfinement for lambing, feeding, and breeding; (3) range or pasture production with open-front lambing facility, and (4) range or pasture production with no lambing shelter. The four sheep facility systems are described in more detail below.

The total confinement system carries out lambing, breeding, and special treatments of ewes in enclosed environmentally controlled buildings. Lambs are fed and finished in an outdoor feedlot with a complete ration. Pastures are available to ewes only when they are not undergoing special treatment. Lambs are not put to pasture. Improved lambing and weaning rates require one-eighth more feed during lactation for ewes.

The semiconfinement system is the same as the total confinement system, except that special treatments are carried out in open-front buildings. Pasture for ewes and rams provides five-eighths of roughage consumption. Lambs are finished in a feedlot with a complete ration.

Range production with lambing shelter provides open-front buildings for lambing only. Ewes obtain half of their roughage from pasture, one-eighth from harvested roughage, and three-eighths from range. Lambs are finished on pasture and range.

Range production with no buildings carries out lambing and other operations on pasture or range with

Table 10--Management practices possible with four production systems

| Management practices | Total confinement 1/ | Semiconfinement 2/ | Range with lambing shelter 3/ | Range with no shelter 4/ |
|---|---|---|---|---|
| Intensive selection | Yes | Yes | No | No |
| Crossbreeding | Yes | Yes | Yes | Yes |
| Multiple birth inducement | Yes | Yes | No | No |
| Out-of-season mating (hormones) | Yes | Yes | No | No |
| Out-of-season mating (light control) | Yes | No | No | No |
| Artificial insemination | Yes | Yes | No | No |
| Lamb nursery | Yes | Yes | No | No |
| Disease and parasite treatment | Yes | Yes | Some | No |
| Pregnancy checking | Yes | Yes | No | No |
| Rigid culling practices | Yes | Yes | No | No |
| Feed diet alteration | Yes | Yes | No | No |
| Predator avoidance | Yes | Yes | No | No |
| Ram fertility checking | Yes | Yes | No | No |
| Early weaning and rebreeding | Yes | Yes | No | No |
| Temperature and environment control | Yes | Some | Little | No |
| Lamb creep feeding | Yes | Yes | Yes | Yes |
| First year lambing | Yes | Yes | Yes | Yes |
| Synchronized breeding | Yes | Yes | No | No |
| Synchronized lambing | Yes | Yes | No | No |
| Hand mating | Yes | Yes | No | No |

1/ Uses totally enclosed buildings, allowing light and temperature control, for lambing, breeding, and feeding. Outdoor pens and pastures are also provided but used only when ewes are not undergoing special lambing, breeding, or feeding treatments.
2/ Uses enclosed buildings for lambing and open-front buildings and lots for breeding and feeding. Pastures are available but used only when ewes are not involved in special treatments.
3/ Open-front buildings with minimum facilities used only for lambing and severe weather shelter.
4/ No buildings or pens provided. Breeding and lambing are done on the range or pasture with minimal observation.

little supervision. Ewes obtain half of their roughage from pasture, one-eighth from harvested roughage, and three-eighths from range. No grain is fed to ewes. Lambs are finished on pasture and range.

With the total confinement facility, all known technologies and practices could be implemented. With the semiconfinement facility, all new technologies could be applied except those (such as light control for out-of-season estrous inducements) that require a high degree of environmental control. The third system--range or pasture production with open-front lambing facility--is highly typical in the sheep industry, but does not allow intensive treatment of ewes and lambs for production improvements. The fourth system is also common, but allows little managerial control.

The systems vary greatly in investment cost but, just as important, vary in their productivity and require large differences in managerial technique. The high-investment total confinement system is currently used by few commercial sheep producers but is often found in research institutions. The semiconfinement system requires a fairly high investment cost, though somewhat lower than that of the total confinement system, but has the capability for implementing nearly all of the available technologies in sheep production. Table 11 compares the potential risk, productivity expectations, and level of managerial control for the four types of facilities.

Table 11--Comparison of potential risk, productivity, and managerial control for four sheep production systems

| Item | Total confinement | Semi-confinement | Range with lambing shelter | Range with no shelter |
|---|---|---|---|---|
| Productivity | high | high | medium | low |
| Risk of large financial loss | high 1/ | low | low | medium |
| Facility investment | very high | medium | low | low |
| Managerial ability | very high | high | low | low |
| Disease and health problems | medium | medium | low | low |
| Ewe and lamb loss | low | low | medium | high |
| Innovation adoption potential | very high | high | low | none |
| Control of production system | very high | high | low | none |
| Predator problems | very low | low | high | very high |

1/ Due to very high investment per ewe.

Reproductive expectations for the four sheep production systems are shown in table 12 for a flock of 1,000 ewes. Two lambings yearly per ewe were assumed for the total confinement system, three lambings in two years for the semiconfinement system, and one lambing per year for the other two systems. Lambs born alive per year for each ewe in the flock are assumed to average 3.60, 2.78, 1.30, and 1.17, respectively, for the four systems. In addition to higher lambing frequency, the more intensive systems are expected to have larger litter sizes, lower death losses, and earlier age at first lambing; but conception rate for the twice a year lambing system is lower, as shown in the table.

## ECONOMIC COMPARISONS OF FOUR SHEEP PRODUCTION SYSTEMS

Comparisons of costs and returns related to sheep production systems involve not only productivity comparisons as presented in the preceding sections, but estimates of facility requirements and investment,

Table 12--Reproduction expectations for four sheep production systems, 1,000 ewes

| Item | Unit | Total confinement | Semi-confinement | Range with lambing shelter | Range with no shelter |
|---|---|---|---|---|---|
| Lambing frequency per year | No. | 1/ 2 | 2/ 1.5 | 1 | 1 |
| Ewes in flock | do. | 1,000 | 1,000 | 1,000 | 1,000 |
| Ewes lambing | do. | 900 | 950 | 930 | 900 |
| Ewes lambing | Pct. | 90 | 95 | 93 | 90 |
| Lambs born live per ewe lambing per lambing | No. | 2 | 1.95 | 1.4 | 1.3 |
| Lambs born live per ewe lambing per year | do. | 4 | 2.93 | 1.4 | 1.3 |
| Lambs born live per ewe in flock per year | do. | 3.6 | 2.78 | 1.3 | 1.17 |
| Lambs born live per year | do. | 3,600 | 2,780 | 1,302 | 1,170 |
| Lambs weaned per year | do. | 3,420 | 2,502 | 1,016 | 819 |
| Lambs raised per year | do. | 3,386 | 2,452 | 965 | 753 |
| Death loss birth to weaning | Pct. | 5 | 10 | 22 | 30 |
| Death loss weaning to market | do. | 1 | 2 | 5 | 8 |
| Female lambs entering breeding flock 3/ | No. | 330 | 300 | 250 | 250 |
| Ewe death loss | Pct. | 1 | 1.5 | 3 | 5 |
| Age at weaning | Mo. | 0.7 | 2 | 4 | 4 |
| Age at first lambing | do. | 12 | 12 | 14 | 15 |
| Lambs for sale per year | No. | 3,056 | 2,152 | 715 | 503 |

1/ Twice-a-year lambing, per ewe.
2/ Three lambings in 2 years per ewe.
3/ Ewes under the intensive systems are assumed to have higher culling rates due to the increased lambing frequency.

direct and indirect costs, and market prices for lambs, ewes, rams, and wool. Net returns depend on the above factors and others.

The four sheep production systems described in the previous section were budgeted and compared. The assumptions were idealized to some extent--that is, the estimates of productivity may not represent that seen in actual practice because few, if any, commercial systems use all the practices assumed in this analysis. The results represent more the perceived potential for intensive sheep production than that found in actual practice. The high levels of productivity have been achieved in short-term research experiments and are used to indicate the potential that exists. The investment costs, feed, labor, and other expenses are budgeted at early 1979 levels.

Table 13 indicates investment levels, direct and indirect costs, income levels, and net returns that may be expected under a given set of normalized assumptions for a flock of 1,000 ewes. High levels of investment are required for intensive sheep production. Investments were assumed to be $364, $254, $119, and $84 per ewe for the four systems in order of their intensity. Annual fixed costs associated with these levels of investment were $52, $36, $12, and $6 per ewe for the four systems, respectively.

Feed costs per ewe were $118, $84, $34, and $25 for the four systems and are higher for the more intensive systems because of the greater number of lambs being produced per ewe and because of the type of feed--less intensive systems use primarily pasture and range while intensive systems require mostly grains and harvested roughages.

Labor involvement for the two intensive systems was estimated to be nearly triple that for the other systems. Hours required per year for the four systems in order of their intensity were 8,420, 7,485, 2,502, and 2,397. Labor tasks utilized by the two highly intensive systems and not needed by the others may include: hand mating or artificial insemination, hormone treatments, special care at lambing, bringing

Table 13--Estimated investment, costs, and returns for 1,000 ewes under four facility systems using appropriate technologies, three lamb price levels

| Item | Total confinement | Semi-confinement | Range with lambing shelter | Range with no shelter |
|---|---|---|---|---|
| | 1,000 dollars | | | |
| Investment: | | | | |
| Buildings | 200 | 80 | 30 | 0 |
| Corrals, working facilities | 30 | 40 | 10 | 5 |
| Equipment | 30 | 30 | 5 | 5 |
| Livestock at $60 per ewe | 60 | 60 | 60 | 60 |
| Land, 20 acres owned at $700 per acre | 14 | 14 | 14 | 14 |
| Machinery and trucks | 30 | 30 | 0 | 0 |
| Total investment | 364 | 254 | 119 | 84 |
| Direct costs: | | | | |
| Feed 1/ 2/-- | | | | |
| Grain, supplement, or complete feed | 73.67 | 57.31 | 10.34 | 2.38 |
| Harvested roughage | 44.42 | 15.68 | 6.87 | 6.82 |
| Pasture and range | 0 | 11.48 | 16.55 | 16.08 |
| Ram replacements | 2.20 | 2.20 | 1.95 | 1.95 |
| Veterinary medicine 3/ | 5.00 | 4.10 | 2.60 | 2.40 |
| Marketing 4/ | 6.62 | 4.76 | 1.82 | 1.39 |
| Utilities, fuel, bedding, supplies | 7.77 | 5.50 | 2.15 | 2.04 |
| Labor, including operator 5/ | 33.68 | 29.94 | 10.01 | 9.59 |
| Shearing, at $1.25 per animal shorn | 1.70 | 1.67 | 1.61 | 1.61 |
| Total direct costs | 175.06 | 132.64 | 53.90 | 44.26 |
| Fixed costs: | | | | |
| Depreciation 6/ | 16.0 | 11.9 | 2.4 | 0.8 |
| Interest (10 percent of one-half of 1979 value) | 18.2 | 12.7 | 6.0 | 4.2 |
| Repairs (5 percent of 1979 value) | 14.5 | 9.0 | 2.3 | 0.5 |
| Property taxes (0.5 percent of total value) | 1.8 | 1.3 | 0.6 | 0.4 |
| Insurance (0.5 percent of total value) | 1.8 | 1.3 | 0.6 | 0.4 |
| Total fixed costs | 52.3 | 36.2 | 11.9 | 6.3 |
| Total annual costs | 227.36 | 168.84 | 65.80 | 50.56 |
| Income: | | | | |
| Market lambs, 110 pounds at $0.65 per pound | 218.5 | 153.9 | 51.1 | 36.0 |
| Culling breeding ewes, 140 pounds at $0.23 per pound | 10.3 | 9.2 | 7.1 | 6.4 |
| Wool, 8 pounds per animal at $1.15 per pound | 12.5 | 12.3 | 11.9 | 11.9 |
| Cull breeding rams, 190 pounds at $0.23 per pound | 0.5 | 0.5 | 0.6 | 0.6 |
| Total income | 241.8 | 175.9 | 70.7 | 54.9 |
| Total income minus total costs | 14.44 | 7.06 | 4.90 | 4.34 |

See footnotes at end of table.

Continued

Table 13--Estimated investment, costs, and returns for 1,000 ewes under four facility systems using appropriate technologies, three lamb price levels--Continued

| Item | Total confinement | Semi-confinement | Range with lambing shelter | Range with no shelter |
|---|---|---|---|---|
| | 1,000 dollars | | | |
| Returns at various lamb prices: | | | | |
| At $65 per hundredweight-- | | | | |
| Total income minus total costs | 14.44 | 7.06 | 4.90 | 4.34 |
| Return to labor and management | 48.12 | 37.00 | 14.91 | 13.93 |
| Return to total investment | 32.64 | 19.76 | 10.90 | 8.54 |
| Rate earned on total investment: (Percent) | 9.0 | 7.8 | 9.2 | 10.2 |
| At $75 per hundredweight-- | | | | |
| Total income minus total costs | 48.48 | 30.70 | 12.79 | 9.84 |
| Return to labor and management | 82.16 | 60.64 | 22.80 | 19.43 |
| Return to total investment | 66.68 | 43.40 | 18.79 | 14.04 |
| Rate earned on total investment: (Percent) | 18.3 | 17.1 | 15.8 | 16.7 |
| At $55 per hundredweight-- | | | | |
| Total income minus total costs | -19.17 | -16.64 | -2.94 | -1.23 |
| Return to labor and management | 14.51 | 13.30 | 7.07 | 8.36 |
| Return to total investment | -0.97 | -3.94 | 3.06 | 2.97 |
| Rate earned on total investment: (Percent) | -0.3 | -1.6 | 2.6 | 3.5 |

1/ Nutrition requirements are from several publications but mainly from (28, 29, 32, 33, 37).

2/ Feed prices per ton:

| | |
|---|---|
| Hay | $ 55 |
| Silage (hay equivalent) | 55 |
| Pasture (hay equivalent) | 25 |
| Range (hay equivalent) | 10 |
| Supplement (44 percent protein) | 240 |
| Lamb creep mix | 120 |

3/ Veterinary and medicine were $1.60 per ewe and ram and $1 per lamb.

4/ Marketing costs were $1.50 per ewe and ram and $2 per lamb.

5/ Total labor at $4 per hour assumed 5 hours per ewe and 1 hour per lamb under the two intensive systems and 2 hours per ewe and 0.5 hour per lamb under the other two systems.

6/ Depreciation levels assume average periods of use as follows: buildings, 25 years; corrals, 15 years; equipment and machinery, 10 years.

feed to the animals, lamb nursery operation, pregnancy checking, recordkeeping, and upkeep on facilities and equipment. Too, the intensive systems are handling three to six times as many market lambs as the other systems. The two intensive systems with 1,000 ewes are essentially three-person operations while the other systems are one-person operations with a small amount of part-time help.

Market prices for lambs have increased dramatically in recent years, averaging near \$65 to \$70 per hundredweight during 1978 and 1979 (table 1). The prices for market lambs assumed for this analysis reflected three alternative levels--\$55, \$65, and \$75--and potential net returns varied widely depending on the price assumed.

Three measures of profitability are useful in determining whether an investment is feasible and in comparing alternative production systems:

- Net return to management is the residual after all annualized income and costs (including a wage for the operator and all other labor) are considered. In table 13, it is the figure associated with "total income minus total costs." The enterprise system that yields the highest positive net return to management should be the one chosen (from an economic standpoint).

- Return to labor and management is calculated by adding back labor charges to net return to management. This measure divided by labor hours indicates the hourly wage rate that could be paid to family and hired labor and still break even.

- Return to total investment is calculated by adding back interest charges to net return to management. This measure allows a comparison of expected rate earned on capital invested for the alternative systems. The producer-investor should expect his rate earned on capital to at least exceed the average interest charges for borrowed capital plus an opportunity return on his own capital. Thus, at current interest rates, he should expect a rate earned on total capital to be at least 10 percent. Otherwise, he could more profitably invest in some other enterprise or place his owned investment capital in an interest-bearing account.

Producers may wish to utilize all three (or other) measures of expected profitability in an enterprise choice or they may wish to emphasize one of the three depending on how they value the labor input or on their level of borrowed capital.

Net return to management with all costs and returns considered is positive for all four systems budgeted at $65 and $75 lamb prices, but negative for the $55 level. The total confinement system proved the most profitable at the $65 and $75 lamb prices, but had the greatest loss at the $55 price level. This reflects the contention from table 11 that the higher intensive systems have both higher potential productivity and higher risk of financial loss. These figures indicate that investment in confinement facilities for lamb production would be profitable under current conditions only for market lamb prices above $60 per hundredweight unless the producer is able to reduce labor or other costs or unless his interest payments are low due to low amounts of borrowed capital.

Return to labor and management under the assumed conditions was positive at all three lamb price assumptions. The maximum hourly wage that could be paid and still cover all other costs for the four systems in order of their intensity were: $9.76, $8.10, $9.11, and $8.10 at the $75 lamb price; $5.71, $4.94, $5.96, and $5.81 at the $65 lamb price; and $1.72, $1.78, $2.83, and $3.49 at the $55 lamb price.

Rates earned on total invested capital were quite similar for all four systems, ranging from 15.8 to 18.3 percent for the $75 per hundredweight lamb price assumption. At the $65 lamb price, rates were between 7.8 and 10.2 percent for the four systems. The rates were negative at the $55 lamb price for the two intensive systems (table 13).

The facility investments as well as other assumptions used in this analysis were of necessity generalized and may not be applicable to all producers. Each producer has unique managerial skills as well as land, facilities, capital, and other assets that may contribute to or detract from success in adopting innovations and utilizing intensive systems in sheep production. The assumptions should be modified by individual producers to account for their locality and assets in considering intensive sheep production.

## POTENTIAL IMPACT ON THE SHEEP INDUSTRY

Technology is now available to fashion a management-intensive, highly automated lamb production system with the following characteristics: Breeding of ewes is done by hand mating and artificial insemination. Light control and hormones enable lambing in every month of the year, mostly during daylight hours. Some lambs are reared in a nursery from the second day of life; others are weaned at 2 weeks so their dams can be rebred 4 to 5 weeks after parturition. Ewes are expected to bear twins or triplets twice a year. Feed rations are adjusted optimally for the age, weight, and sex of the lambs and stage of pregnancy and body condition of the ewes. Ewes are bred to lamb at 1 year of age. Ewes genetically selected for multiple births are bred with rams selected for rapid growth traits. Market lambs are fed high-energy rations and marketed at 120 to 150 pounds.

All those characteristics have been achieved for short time periods under experimental conditions. Producers are beginning to recognize the potential for intensive sheep production systems which incorporate new technologies and management practices. However, adoption may be slow in the industry because of high investment costs, unavailability of some needed hormones, the need to overcome some problem areas such as disease control, the need to assemble highly qualified managerial expertise, and the necessity of assembling a prolific flock of ewes and rams adapted to the intensive system. The price incentive for mass production of sheep has also been lacking until recently. Current price incentive together with the combination of new technologies and improved management practices make feasible the consideration of lamb factories as described above.

The potential impact on the sheep industry of gradual, widespread adoption of the innovations discussed in this publication may include:

- A gradual increase in sheep numbers in the United States particularly in grain-producing areas like the Midwest.

- An increase in lamb production, stemming the further decline in the number of slaughter plants handling sheep and increasing the numbers of such plants.

- An increase in the number of facilities in which sheep are kept partially or totally confined.

- Increased net returns to sheep producers.

- Increased understanding by producers of the production potential of sheep.

It should be noted that a larger supply of sheep in the United States would lower the price level, unless consumer demand for lamb increased proportionately. Farm-level lamb prices rise as population and incomes increase and decline as lamb, pork, and beef production increase. U.S. lamb prices decline 0.42 percent for each 1-percent increase in lamb production per capita (41, p. 7). However, as per capita disposable income increases 1 percent, lamb price will increase 1.09 percent. Thus, over time, assuming continued increasing personal incomes, lamb production can increase substantially without adversely affecting lamb price levels. Therefore, a gradual increase in lamb production, as producers adopt innovations in sheep production, will probably not have a significant effect on lamb price.

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