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Economic Evaluation of Breeding Objectives for Sheep and Goats: Practical Considerations and Examples

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Economic Evaluation of Breeding Objectives for Sheep and Goats: Practical Considerations and Examples

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Summary

Examples of breeding objectives for sheep industries with well developed breeding programs such as in Australia and New Zealand are reviewed briefly. For industries lacking adequate information on genetic and economic parameters to quantify objectives precisely, some general guidelines for choice of objectives are outlined, and it is suggested that considerable genetic progress can be made in such industries by use of sound objectives in choice of breeds, breed combinations or base populations for multiplication. Objectives which it is suggested merit increased attention include: (1) defining optimum litter size and mature size; (2) improving lamb viability; (3) improving longevity and disease resistance; (4) reducing labor requirements (improving easy care traits); (5) improving feed conversion; (6) reducing seasonality of breeding; and (7) reducing variability in litter size. Breeding objectives for goats are discussed briefly.

I. Introduction

Sheep and goats are kept for the production of meat, fiber and milk, the relative importance of each depending upon locale. Breeding objectives must relate to the economics of production efficiency for the product or products of concern.

Relative to other domestic species, sheep and goats tend to utilize lands of lower production potential. Income per animal tends to be less than for cattle or swine, an important factor when considering performance recording costs.

While assessment of breeding objectives has received much more attention for sheep than for goats, there is much overlap where the product (e.g. meat) is the same. Accordingly, discussion here will focus on sheep, with comments specific to goats to follow.

The wide range of production environments and management systems under which both species are kept is matched only by the diversity of breeds and breeding systems used. The types of breeding/production systems can be divided into three broad categories:

1. Breeds maintained and used primarily as purebreds:

Under relatively harsh conditions and extensive management, important attributes include adaptability, hardiness, and breeding season suited to the feed cycle, while optimum prolificacy and growth rate may be fairly low. Breeds in this category include a range of wool breeds (Merino, Scottish Blackface), fat tail breeds (Awassi) and hair breeds (Sahelian hair sheep).

Breeds kept under better nutrition/management levels tend to be dual purpose breeds for which at least moderate levels of prolificacy, growth and milk production are important in addition to good wool production. Examples include the Romney and its derived breeds in New Zealand and the Targhee and Columbia breeds of the U.S.

Surplus or cast for age ewes from either of the above situations are frequently used in crossbreeding systems, either to produce market lambs (e.g. Suffolk x Rambouillet, U.S.) or specific cross daughters for use in other environments (e.g. Border Leicester x Merino, Australia; Scottish Halfbreds, U.K.). Nevertheless, the breeding objective for such breeds must focus on their performance in the primary environment.

2. Specialized "ewe sire" breeds:

Several breeds find their major role as sires of crossbred commercial ewes. Examples include Finnsheep, Border Leicester, and East Friesian. Important attributes contributed may include prolificacy, milk production, growth rate and/or long breeding season. Since the merits of these breeds depend on genetic expression in crossbred daughters, breeding objectives must be formulated accordingly.

3. Terminal sire meat breeds:

Important attributes for such breeds include the livability, growth and carcass merits of crossbred progeny. The most important purebred traits are libido and fertility combining to produce high conception rates at low ram:ewe ratios. For terminal sire breeds such as Suffolk, Texel, Ile-de-France and Southdown, breeding objectives must consider both purebred ram and crossbred lamb performance.

II. Traditional objectives

The following examples of breeding objectives for sheep are divided into sections dealing with:

1. Relatively "mature" industries, characterized by:
   - well established breed types and markets
   - good estimates of genetic and economic parameters
   - operational systems for recording and utilization of performance data for a large segment of the seedstock industry.
2. Less well developed industries, characterized by:
   - few parameter estimates
   - breed types and markets not well defined
   - few or no performance data available

It is recognized that there may be a continuum between these two situations. For example, in the U.S. sheep industry, the first two conditions listed under 1 are fairly well satisfied, but the third is not.

1. <u>Mature sheep industries</u>

As defined above, breeds or breed combinations are relatively well established in these systems, and the focus here is on the further improvement of existing stocks. However, judicious introduction and use of inheritance from other breeds, to meet new improvement goals or to accelerate attainment of existing ones, may also be an option.

Breeding objectives have been worked out in some detail for within population improvement for the Australian and New Zealand sheep industries.

Turner (1979) presented a comprehensive discussion of traits of economic importance in the Australian sheep industry. Jones (1982) developed selection indexes for Merino sheep, and concluded that grease fleece weight and fiber diameter were much more important than live weight or number of lambs born; inclusion of feed intake in the breeding objective increased the relative emphasis on fleece traits. With regard to number of lambs born, it was pointed out that availability of a better criterion for assessing breeding value for the objective in question, increasing number of lambs weaned, would result in increased weight given to reproduction. Ponzoni and Walkley (1984) examined the value of number of lambs weaned (NLW) in breeding objectives for Australian Merino sheep. The effect of including NLW varied markedly, depending on flock structure, estimated costs of increased reproductive rate, and number of dam's NLW records available. Assuming that there is not a feed surplus and thus that increased reproductive rate will lead to a decrease in stocking rate, the contribution of NLW was always less than 40% of the total gain (from use of an combining clean fleece weight [CFW], fiber diameter [FD], weaning weight r hogget weight [HW], and NLW), and in some cases was less than 10%. i (1986) extended the analyses of objectives for Merino sheep to include r range of values for economic variables, including feed costs. As ed, increases in meat prices and/or decreases in feed costs decrease the c change in wool and increase the genetic change in NLW and body weight feed intake) from use of the optimum index.

Morris et al (1982), taking as a general objective the increase of net e per hectare, developed breeding objectives for several segments of the ealand Sheep Industry.

Their index for general purpose breeds such as the Romney used in ghbreeding, was

$$I_1 = 33.9(NLW) + .56(WW, kg) + .34(D\%) + 0(ECW) + 6.42(GFW, kg)$$

where NLW and WW are as defined earlier
D% = dressing %
ECW = ewe carcass weight
GFW = grease fleece weight

The estimated increased income per ewe lifetime from use of this index lection differential = σ_I for five generations) was $1.51, 64% from rovement in NLW, 11% from WW, and 26% from GFW.

These authors concluded that there would be no economic gain from cluding wool quality traits in the index for Romney sheep. Wickham and Pherson (1985) reached the same conclusion, but pointed out that emphasis on eece weight is expected to result in favorable changes in wool quality traits such sheep.

Morris et al (1982) pointed out that if the objective is to breed dams of ime lambs, the relative weights for weaning weight and dressing percent ange in proportion to the dam's contribution (50%, + maternal influence). e of the optimum index is then estimated to result in more improvement for ol, less in weaning weight and ewe carcass weight, and little change, mpared to I_1, in NLW and D%. The authors concluded that the differences were obably not great enough to justify two sets of objectives for such breeds. nzoni (1982a) concluded that this was true also for Australian Merinos.

For fine-woolled breeds, breeding objectives recommended by Morris et al 982) were similar to those for Romneys, but with the addition of staple ngth and fiber diameter. Number of lambs weaned here also was estimated to ntribute over 50% of the monetary value of genetic change, and fleece weight s the most important wool trait. The different conclusion with regard to the portance of reproduction for fine woolled sheep, compared to those of Jones 982) and Ponzoni and Walkley (1984) appears to be due to consideration of fferent breeds, and different estimates for feed costs and meat prices.

With regard to terminal or prime lamb sire breeds, breeding objectives nd to be simpler, in that prolificacy, breeding season and wool production e largely irrelevant. The two most important traits then become growth rate d lamb livability. Morris et al (1982) estimated that, under New Zealand nditions, growth rate was twice as important as lamb livability.

The value of including carcass composition in the objective has been nsidered by several authors. Although inclusion of percent lean in the rcass as a selection criterion could increase rate of genetic improvement in an meat production per animal by an estimated 20 to 50% (Bradford, 1967), the st of progeny testing to accomplish this does not appear to be justified cept possibly with use of the selected sires through artificial insemination, in the top stratum of seedstock flocks in an industry which paid on the sis of carcass lean content (Bradford 1967, 1974). Furthermore, it appears that in practice selection on growth rate alone will increase weight of lean meat almost as rapidly as selection on an index combining growth rate and carcass lean content (Bradford, 1967; Bradford and Spurlock, 1972; Olson et al., 1976b). With regard to improving growth rate, Olson et al (1976a) found that gain from 14-22 weeks would be the most effective selection criterion for U.S. market conditions. The conclusion from these and other studies (e.g., Dickerson 1978, 1982) is that genetic improvement of growth rate is an important objective in at least terminal sire breeds. This assumes no adverse correlated effects, which may in fact exist (see sections II, 2 and III).

Formal evaluation of breeding objectives for sheep appears to have been confined largely to the work on fine wool and dual purpose breeds in Australia and New Zealand, and a limited amount of work on dual purpose and meat breeds in the U.S. and Europe. The difficulties of standardizing selection objectives and procedures, due to different markets, flock sizes, degrees of recording and other factors, are illustrated by the report on work in Europe by Croston et al (1980).

2. Less developed industries

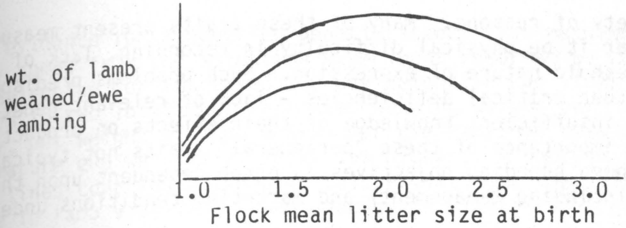
In many countries where sheep are important, in both the developed and developing world, quantitatively defined breeding objectives such as those for Australia and New Zealand described in section II,1 are not yet available.

Performance recording is generally assumed to be essential to establishment of a successful breeding program (e.g. Ponzoni, 1982). However, organization of comprehensive performance recording schemes may not be feasible for some time to come in many countries which would like to make genetic improvement in their sheep and goat populations. Does this mean that genetic improvement is not possible in these situations?

In some cases, significant genetic improvement can be made, without extensive recording schemes. The approaches available include: (1) use of breed resources (local, or local and imported), and (2) screening local populations for superior individuals, and their multiplication and distribution. Use of major genes is a possible third approach which may have applicability in some cases. These approaches are not a substitute for longer term improvement programs based on recorded performance, but can be used as productive initial steps which may pave the way for development of improvement programs based on continuously recorded performance.

Definition of objectives is important both in the choice of stocks to be used and in effecting further improvement within stocks. Quantification of objectives is difficult in the absence of good data from the environment in question. Nevertheless, guidelines based on the contribution of different components of performance to efficiency in other environments may be helpful in establishing objectives; this approach may also help define what information is most needed.

a. An increase in number of lambs weaned per ewe mated, of which the most important component generally is litter size (mean number of lambs born per ewe lambing), will in many breeds and production environments result in an increase in efficiency of production and returns. However, the optimum litter size varies with feeding and management level, and establishment of an appropriate objective requires knowledge of the optimum for that particular production system.



The different curves represent different levels of feeding and management. Given information on which curve applies in a particular environment, and on the mean litter size of local breeds, one can decide whether an increase in litter size is desirable. If an increase is indicated and breeds with higher prolificacy which transmit their superiority additively (such as the Finnsheep, Romanov and D'Man) are available or can be obtained, one can estimate the proportion of prolific sheep inheritance which should be incorporated to reach the optimum. One needs also to compare estimated benefits with estimated costs, in terms of (i) costs of importation (if necessary), (ii) losses in other traits such as fleece weight or quality, (iii) additional feed and management costs required to realize the potential benefits of the new type. Estimates of some of these costs, and also of time lags involved in implementing such a program, are given by Desvignes <u>et al</u>. (1974).

b. Improvements in genetic potential for fiber quantity and quality generally require less change in feeding and management than increases in prolificacy, milk production or growth potenial. Fiber traits are also in general easier to evaluate than these other traits, and more highly heritable. Thus if fiber is an important source of income to the sheep or goat industry of an area, it may represent a logical starting place for initiation of a genetic improvement program.

c. Improvements in carcass conformation and composition generally contribute much less to increased returns (see section II,1) than improvements in reproduction, fiber production or growth. This is likely to be especially true where there is no carcass grading system.

d. Marked increases in growth rate and mature size, either through selection within populations or introduction of larger breeds, are not necessarily advantageous. The reasons involve: (i) the association between size and fitness (see section III), (ii) the superior ability of small and medium sized breeds to reach market finish during the short season of adequate feed characteristic of many sheep production environments, (iii) quantitative estimates of the importance of body weight in breeding objectives for wool or dual purpose sheep, especially where feed intake is considered, are fairly low (Ponzoni, 1982b; see also section II,1), (iv) the absence of any inherent association between size and life cycle efficiency (e.g. Dickerson, 1978; Taylor, 1985). Nevertheless, many national breeding programs in developing countries (as well as actual practice in many purebred industries in developed countries) give top priority to increasing growth rate and mature size. This is the area where economic evaluation of breeding objectives for sheep is perhaps most needed.

III. Other potentially important breeding objectives.

James (1982) emphasized the importance of including every trait of economic importance in the breeding objective and advocated including traits such as feed consumption even though it may be impossible actually to use such a trait as a selection criterion. There are numerous traits which are probably important in determining sheep profitability but which are difficult to deal with for a variety of reasons. Many of these traits present measurement problems, whether it be physical difficulty in recording, lack of an objective scale, or a threshold nature of expression. Such problems predispose these traits to two other critical deficiencies - lack of relevant genetic parameter information and insufficient knowledge of their effects on production economics. The importance of these "peripheral" traits not typically considered in sheep breeding objectives is often dependent upon the environmental (including management) and marketing conditions under which they are assessed.

1. Improving lamb viability

While this is obviously an important factor affecting efficiency and net income, it has received surprisingly little attention. Among formally defined breeding objectives one of the very few which includes lamb viability directly is that by Morris et al (1982) (section II,1) for terminal sire breeds. Possible reasons are a low heritability, and scarcity of reliable data. Nevertheless, the contribution of lamb survival rate to meat production in particular is such that, if there is genetic variation in the trait, it should be included in the breeding objective. For example, consider two flocks of 100 ewes each with satisfactory fertility, litter size and lamb weaning weight, but a 5% difference in lamb viability:

Flock	No. ewes	NB	Viability	NW	WW(kg)	TWW(kg)
A	100	5x0				
		50x1	.88	44.0	40	1760
		45x2	.82	73.8	35	2583
Flock totals				117.8	36.9	4343
less 25 replacements				92.8		3421
B	100	5x0				
		50x1	.83	41.5	40	1660
		45x2	.77	69.3	35	2425
Flock totals				110.8	36.9	4085
less 25 replacements				85.8		3163

With 25 weaned lambs in each flock saved as replacements, flock A will have 8% more weight of lamb to sell per year than flock B.

Evidence for genetic variation in viability was summarized by Cundiff et al (1982), who computed an average estimate of .08 for heritability of lamb survival as a trait of the dam, while the few estimates for this parameter as a trait of the lamb were lower. Clearly, potential response from mass selection is low. However, evidence for between breed variation is substantial (e.g. Carter and Kirton, 1975; Dickerson, 1977; Magid et al, 1981a,b; Cundiff et al, 1982). With the exception of the Border Leicester breed, for which both direct and maternal effects on viability are low compared to those of other breeds regardless of size (McGuirk et al., 1978; Magid et al., 1981a,b), the pattern is for breeds of larger mature size to transmit lower viability (Bradford et al., 1960; Fahmy et al., 1972; Carter and Kirton, 1975; Dickerson, 1977). The differences are in several cases quite large, often more than offsetting substantial differences in lamb growth rate. For example Dickerson (1977) reported that Suffolk-sired crossbred lambs produced 9% more meat per lamb than Oxford-sired crossbred lambs, but 11% less per ewe, because of higher mortality.

Further evidence for a negative genetic association between growth rate d viability comes from the selection experiment reported by Lasslo et al 985a,b). Selection for increased 120-day weight in two lines of Targhees, e replicated in two locations, increased weaning weight per lamb gnificantly, but weight of lamb weaned per ewe remained constant or decreased spite of mature ewe weights at least 15% higher. A decline in fertility in e selected lines contributed some to this result, but the principal factor s a decline in lamb viability. The changes in viability of the 3 lines, in mparison with unselected controls, were -2.0, -2.4 and -3.1% per kg increase 120-day weight. A decrease of only 1% in viability per kg increase in eaning weight would eliminate approximately 40% of the economic benefit of the ncreased weaning weight.

These results, considered together with the breed comparisons, suggest hat there is considerable genetic variation in viability, and that at least a art of this is associated (negatively) with growth rate. Thus economic enefits from increased genetic potential for growth may not be realized unless ttention is paid simultaneously to viability. This may be particularly true f terminal sire breeds, in which selection for increased mature size is currently quite intense, at lease in the U.S. The breed differences also suggest that more efficient crossbreeding systems can be devised if breed differences in direct and maternal effects on viability are taken into account (Cundiff et al., 1982).

2. Improving longevity and disease resistance

Longevity is a function of both death loss and culling decisions based on actual or anticipated substandard production. Death losses have an obvious effect on economic returns since dead sheep seldom have a significant salvage value in any management system. The costs of culling are highly dependent upon the difference between salvage value and replacement costs.

In situations where animal sale value is determined solely by weight, a mature cull breeding animal may be worth more than its replacement. On the other hand, in markets such as the U.S. where mutton is of little value compared to lamb, culls may be worth less than 20% of the cost of replacements. In such situations of high "depreciation", one extra year's productivity may be a major factor in the animals' profitability.

Selecting animals at a young age to shorten generation intervals has largely precluded considering longevity in breeding programs. In fact, selection for higher producing animals with greater attendant nutrient requirements may lead to reduced longevity. For instance, the effect of rearing twins on a ewe's body condition and subsequent performance are well known, particulary in harsh environments.

Factors which influence longevity may differ dramatically among environments. Such factors include climatic differences, exposure to disease or parasitic organisms, and ability to secure adequate nutrients. The importance of genotype x environment interactions quickly becomes evident when exotic genotypes are introduced, as witnessed in recent years through the widespread attempted exploitation of Finnsheep genes.

The wisdom of including disease or parasite resistance as a breeding objective clearly depends upon its economic importance in production and the costs of its inclusion as a selection criterion vs. handling the problem by alternative (e.g. therapeutic) means. Unless other physiological "markers" are available, measurement of resistance is possible only in the presence of challenge. Progress is likely to be greatest when animals can be artificially challenged under standardized conditions.

One example of such an approach is the selection for resistance to facial eczema in New Zealand. Facial eczema is a seasonal problem caused by a ıytotoxin produced under appropriate climatic and pasture conditions. Fungal ·owth and attendant pasture toxicity can vary considerably between icroenvironments within feet of one another, leading to highly variable kposure among animals. Ingestion of toxin results in cumulative liver damage, ith the clinical facial lesions resulting from photosensitivity.

In severe outbreaks, mortality may exceed 50% with many of the liver-amaged survivors later succumbing during the stresses of late gestation or arturition. Heritability of liver damage following toxin challenge was shown o be quite high (h^2 = 0.42, Campbell, et al., 1981). Means were subsequently evised to challenge animals under grazing of toxic pastures and to estimate iver damage through assessment of plasma levels of a specific liver enzyme Towers et al., 1983). The technique has since been refined to include direct hallenge through toxin dosing, thereby allowing ram breeders in non-facial czema regions to select resistant rams for clients in susceptible regions.

Selection for longevity might best be achieved by identifying components vhich lead to premature culling. For example, in many environments teeth wear s a major criterion for culling of breeding ewes. Meyer et al. (1983) ·eported a heritability of 0.46 ± 0.13 for wear rate of permanent incisors in young ewes. If current studies produce similar results for wear rate in leciduous teeth, it may be possible to select directly for reduced teeth wear among young sheep in appropriate environments.

As an alternative to direct selection for components of longevity, age of dam might be included as a selection criterion in selection of replacements. Such an approach might be used by breeders screening ewes for inclusion in a breeding nucleus or by commercial producers in their final selection of performance recorded rams. The negative effect of such selection on generation interval in purebred flocks needs to be considered.

3. Improving easy care traits

Easy care is usually considered as the ability of sheep to produce with a minimum of human assistance or intervention, particularly at lambing time. Lambing difficulty requires added labor inputs and is also associated with increased lamb mortality. In the past, natural selection has strongly favored easy care ewes able to produce and rear vigorous lambs. Management intensification such as provision of shelter, lambing supervision and artificial rearing have greatly increased survival of animals which would otherwise have died. This change has coincided with artificial selection for certain traits which may make sheep increasingly dependent upon human inputs. The showring influence has markedly changed physical characteristics of many breeds. Current U.S. emphasis for extreme size in some breeds appears to be resulting in commercial offspring requiring high levels of lambing assistance. This is hardly surprising when some ram breeders express pride in lambs with 20 pound birth weights!

The advantages of easy care are reflected in both a reduction of production costs (primarily labor) and an increase in productivity through reduced lamb and adult mortality. As with many diseases, easy care is likely to appear as a threshold character making it amenable only to culling of deficient animals rather than intense selection of superior ones. While this would appear to be a rather inefficient means of making genetic progress, anecdotal evidence from purebred and commercial flocks in New Zealand suggest that such an approach has in many cases led to substantial reduction in levels of assistance required at lambing time. It is not possible to tell how much of the apparent improvement is due to accompanying managemental changes or to the producer's perception of the need for lambing assistance. Nevertheless, some genetic pressure is being applied and the Coopworth Breed Society of New Zealand, for instance, withdraws registration from any ewe requiring lambing sistance, and prohibits registration of any lamb assisted at birth. Such gulations will apply indirect selection against structural traits conducive lambing difficulty while encouraging management practices which likewise duce the problem.

Improving feed conversion

The importance of feed conversion as a breeding objective for sheep raised der intensive production conditions is obvious and it can be addressed in the me manner as for other species raised intensively. Under grazing conditions, owever, the ratio of product output to nutrient input may have a range of nterpretations and attendant ramifications. As pointed out by Carter (1982) t is important to distinguish between feed utilization efficiency and feed onversion efficiency. Quite apart from the cost and difficulty of measuring ndividual conversion efficiency under grazing conditions, an efficient onverter may not prove very profitable if it utilizes only a small portion of otential available feed and the unused portion goes to waste. Ample evidence s now available that under high levels of forage production, poor early tilization can lead to a reduction in quantity of forage subsequently roduced. Thus the grazing animal not only harvests forage but can have a major effect on forage production as well.

Stocking rate in most sheep grazing systems is determined by feed availability during troughs rather than peaks in the annual forage cycle. Assuming that feed supplemented during the shortfall period is expensive relative to that grown at other times, the added maintenance requirements of larger sheep during times of supplementation may be large compared to benefits of their more efficient conversion of cheaper grazed forage.

Another important consideration of "efficiency" is the animals' ability to capitalize on feed surpluses during times of plenty in order to overcome feed deficits at other times. Selection for leaner sheep to meet consumer demands may result in breeding animals with reduced fat storage capabilities. The solution to the dilemma may be in selection of extremely lean sire lines for crossing with more robust dam lines to produce slaughter lambs.

5. Lengthening or changing the breeding season

Seasonal breeding is a constraint to sheep production in some environments. The general goal is to lengthen the season and ultimately to eliminate seasonality, either to permit lambing at intervals of less than a year, or to permit lambing outside the normal season, to take advantage of higher prices or to utilize seasonally available feed. With regard to the latter objective, shifting the season without changing the length could also accomplish the desired end.

The economic impact of seasonal breeding appears not to have received much attention in defining breeding objectives. However, the effect of seasonal breeding tendency on net reproductive efficiency at different times of the year can be quite large. For example, Shelton and Morrow (1965) reported 84, 96, 127 and 135 lambs born per Rambouillet ewe put with the rams for 60 days on March 21, June 21, September 21 and December 21 respectively.

On annual grassland range in Mediterranean climates, autumn or early winter lambing is desired. We present here estimates of the effect of delay in lambing over a 3-month period, from, say, October 15 (often the earliest desired lambing date) to January 15 (when ewes of most breeds will lamb). It is assumed that lambs are to be marketed at 5 months of age, weighing 50 kg. Two alternative situations are assumed:

a) The average price of lambs on March 15 is \$1.50 per kg live weight, and declines at 5% per month, or \$.0025/kg/day to June 15. Then the cost of 1 day delay is 50 x \$.0025 or \$-.125/lamb/day. Thus, at 100% lamb crop, a ewe mbing on January 15 will return $11.25 less than one lambing October 15, if l other traits are equal. However, prolificacy tends to increase as the ɛason progresses; an estimate based on data from Iniguez et al. (1986) is an ıcrease of .003 lambs per day over the period in question. (The data of ıelton and Morrow [1985] yield a similar estimate, over a 3-month period ɛginning one month later). All extra lambs born are assumed to be twins and hey and their co-twins will therefore replace singles. Using the viability alues from flock A, section III,1, and assuming that weight and price for wins will be 43.8 kg and $1.40/kg when corresponding values for singles are 50 g and $1.50, yields an estimated increase in income per ewe of .10 per day, ue to the increased prolificacy, nearly offsetting the decline in price.

b) In some situations, seasonal feed supply dictates that all lambs be ıarketed on a fixed date, regardless of age or weight. Lambs which weigh 50 kg ıt 5 months gain approximately .3 kg/day. On this basis, and using the range ɔf prices mentioned above, the reduction in income from later lambing will be $.38 to $.45 per lamb (and per ewe, at 100% lamb crop) per day. In this situation, the increased prolificacy will not compensate for the later lambing, resulting in a net loss of $.28 to .35 per day.

The factors considered in (a) and (b) may both apply in some situations. Also, a number of other factors may of course not be equal, and where feed supply favors early lambing, weather (hence lamb survival), labor, etc may increase the penalty for later lambing compared to these estimates. These estimates suggest that inclusion of earlier conception in the breeding objective could be important. However, quantification of its importance will require estimates of both genetic and economic parameters not yet generally available.

6. Reducing variability in litter size

Of two populations with optimum mean litter size for the environment, the one with the more uniform litter size at birth will wean more total weight of lamb. Bradford (1985) compared two reported populations with the same mean litter size but quite different variation. Assuming mean survival rates of 88, 82 and 50% for singles, twins and triplets, respectively, yielded an estimated reduction of 8.7% in weight of lamb weaned for the more variable as compared to the more uniform flock.

Selection for reduced variation in litter size within a breed may not be effective. However, marked breed differences in pattern of variability occur, and it is suggested this is a factor of sufficient economic importance to merit its consideration when choosing breeds. This would be of particular importance in choosing ewe sire breeds, or breeds to contribute to development of new breeds in this category.

7. Breeding objectives for hair sheep

Hair sheep represent an estimated 7 to 10% of the world's sheep population (Fitzhugh and Bradford, 1983), but their genetic improvement has received little attention to date. Principal breeding objectives will relate to improvement of meat production, and hence will be similar to those directed towards improving meat production from dual purpose breeds. Unfortunately, the improvement efforts which have been made have typically involved crossing with imported wool breeds, and this may well have been counterproductive. Adaptability, particularly in the humid tropics, appears to be impaired (Fitzhugh and Bradford, 1983). The crossbred does not produce a useful fiber (Burns, 1967). The degree of wool cover on ewes of mixed wool-hair sheep populations is negatively associated with weaning weight of their lambs; Odenya (1982) found a highly significant regression of -.93 kg WW per unit increase in wool cover score (1-6 scale) of the dam, in a Dorper flock in Kenya. This

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would mean a difference of 2.8 kg, or 13% of the mean of 21 kg, in adjusted 105-day weight of lamb between dams with wool scores of 2 and 5 (both common in the flock). Odenya (1982) obtained an estimate of .26 for heritability of wool cover score in this population. These results suggest that removal of wool from mixed hair-wool sheep populations (or alternatively their replacement with pure hair sheep) should be considered as part of the breeding objective where hair sheep are the better adapted or preferred type.

IV. Special aspects of breeding objectives for goats.

Breeding objectives for meat goats will be similar to those for improvement of meat production in dual purpose or hair sheep. The need for adaptability to a harsh environment may be even more important in goats than in sheep, on a world wide basis. While within population selection programs are unlikely to place direct emphasis on adaptability, this need should be kept clearly in mind in choice of breeds.

Defining optimum litter size born and mature size for a particular environment will be equally as important for goats as for sheep. Removing seasonal breeding constraints may also be an important consideration in improvement programs for meat goats.

In Angora goats, fiber production is the principal goal, and meat tends to be less important as a byproduct than in even the most specialized breeds of wool sheep.

Breeding objectives for specialized dairy goat breeds will be similar in a number of respects to those for dairy cattle, but with two important additions. Seasonal breeding is a serious constraint to year round milk production, and almost certainly reduction or removal of seasonality should be a part of the breeding objective. However, much research remains to be done in this area, in determining genetic parameters, particulary genetic correlations with other traits, and in identifying appropriate selection criteria. Secondly, there is a need for additional information on the phenotypic and genetic relationships between prolificacy and milk production, and on the effect of variations in prolificacy on net returns from dairy operations.

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