Reproduction and Breeding of Goats

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ABSTRACT

Reproduction and genetics of the goat are reviewed with a view of increasing their contribution to mankind. The goat contributes most in tropical regions (within 30° of the equator). The most important product from the goat is milk with meat a close second. Other products are minor. Reproductive rate is a problem only with the Angora goat, but increased reproduction with any type of goat would contribute to improved efficiency. Also, a knowledge of the reproductive phenomenon is necessary for effective management. Genetic studies of goats are limited, but this should not limit improvement programs. Excellent genotypes for producing milk and fiber are available, but adaptation to tropical conditions is needed. Even within temperate regions, there is little evidence of progress in breeding for milk production. Little has been done on the development of the goat as a meat animal. Also, research on crossbreeding for milk or meat production is limited.

INTRODUCTION

There has been a renewed interest in the contribution of the goat to meeting the world's needs for food. The resources available and their location should be considered in any attempt to maximize contributions of this species. Adaptation to environmental or production conditions is important for any organism, but they may be doubly important for the goat. The world's goat population is displaced toward equatorial or tropical regions with over two-thirds within 30° of the equator. Since land area is generally greater in the lower latitudes, it is more meaningful to look at the ratio of goats to other species (Fig. 1). Goats make their most important contribution in the tropical regions, and any type that is likely to contribute on a world basis must be adapted to this region. This is the area of many of the developing nations. Thus, the importance of the goat is greater than indicated by statistical data, because their products fill a greater need.

From a biological standpoint, why is the goat population greater toward the tropical regions? Their small size, large surface area relative to body weight, and limited subcutaneous fat cover adapt them poorly to cold climates but make them relatively more adapted to areas of high temperatures. There is little evidence that high temperature alone is seriously detrimental to reproductive efficiency of adapted strains of goats, but it may limit seriously growth rate or milk production. The humid tropics present problems of disease and parasitism. Most important, the goat appears to have a superior adaptation to the arid tropics because of its ability to conserve water, travel well, graze selectively, and to take willingly a wide variety of the vegetation (54, 55, 57). Indigenous goats also tend to be resistant to many of the diseases which plague other livestock species in these areas.

Products

Based on UNFAO (United Nations Food and Agricultural Organization) data, the most important products from the goat are milk, meat, fiber, and hides (Fig. 2), and to this list of uses might be added that of laboratory animal and pet. Milk is considered to be the most important use, followed by meat, and compared to these, the other products are much less important. Most goats have the potential to produce all the products enumerated, but it does not seem desirable to attempt to develop a genotype to serve all these functions. Animal protein can be produced more efficiently as milk than as meat (14). Thus, milk production would continue to receive emphasis as a means of meeting needs for animal protein. Claims have been made for greater efficiency of the...
goat as a milk producer as compared to other species. Many of these are based on extrapolations of milk production as a ratio to size or body weight without the benefit of data on feed intake. Devendra (26) summarized the available data relating to efficiency of milk production from goats. These data appear to suggest an advantage for goats. Major differences in partial efficiency occur when animals are compared which have important differences in the genetic potential for a particular trait or when inserted into an environment in which one animal possesses a distinct advantage in adaptation. One of the major advantages of goats is that their small size relative to the cow make them better adapted to smallholder agriculture. Labor requirements for milk production from goats is two to four times that of cattle, and this alone will dictate a secondary position for the goat in many societies whereas in others it will not present a problem.

REPRODUCTION IN THE GOAT

Reproduction is a major contributing factor to efficiency of meat production. Even with animals kept primarily for milk or fiber production, reproduction makes an important contribution by a) influencing the number of surplus animals which may be utilized for meat and b) contributing to current and future production through influencing culling. For Angora goats, reproductive performance has special significance in that surplus bucks are run as castrates for fiber production and as such often are valued more than does. Also, the young animal is a more efficient producer of a better quality fiber (45), and thus, in a stable population, the reproductive rate controls the average age of the flock and influences the quality and efficiency of fiber production. Statistics on the reproductive rate for goats are not reported often. It is only with the Angora that reproduction is a particular problem (85, 100, 101). In the Angora breed, the net kid crop raised in the U.S. on an industry-wide basis is not considered to exceed 50%. With the other types of goats, reproductive rates are undoubtedly the highest of any of the domestic ruminant species, likely being surpassed by only a few of the more highly fertile breeds of sheep such as Landrace or Black Belly Barbadoes. In the U.S., the net kid crops in the range of 100 to 200% would be expected for non-Angora goats under most conditions. Although litter sizes above two are common among well-fed animals, two kids raised may be taken as a practical upper limit from once-per-year kidding. Many types of goats, when run continuously with bucks, kid more often than once annually. Beyond improving the kid crop, a knowledge of the repro-
Productive phenomena of the goat is essential to good herd management. The diversity of genotypes of the goat make it difficult to be specific in discussing the parameters of reproduction. In this connection, more typical values will be given along with a mention of deviates where known.

Puberty

Most goats reach puberty at a relatively young age. Although there are considerable differences between genotypes, the sexes should be separated by or before 5 mo of age. Rogers et al. (76) suggested that pygmy goats may reach sexual maturity as early as 3 mo, and Yao and Eaton (106) found live sperm in the epididymis of dairy goats at 110 days. Skinner (90) reported live sperm in Boer goats at 120 days while Elwishy and Elsawaf (32) found buck Damascus goats reached sexual maturity at 509 days. The report on the Damascus goat is at variance with observations of other kinds suggesting that this animal is reacting distinctly differently. Also, in animals that are subject to high photoperiodicity, the occurrence of seasonal anestrus may delay exhibition of sexual maturity with results that they do not show sexual activity until their 2nd yr. This is the norm for Angora goats. Although most non-Angora goats will exhibit estrus or rut their first season, it is generally advisable that they not be permitted to breed short of 9 to 10 mo or have reached 60 to 75% of mature body weight before breeding to not affect future production adversely. This is especially true for does which are to enter the milking herd. Bucks may be used lightly their first breeding season and for normal service (50+ does per season) thereafter.

Length of Breeding Season

The goat, like many other animals, shows a seasonal cycle in reproductive activity generally relating to the length of the photoperiod (7, 68). With this species both bucks and does are seasonal, and unless several bucks are present, a lack of libido in the buck can present problems. Libido or rut in the buck will affect the occurrence of and the ability to detect estrus in the does (80). Ruttingbucks are distinguished easily by odor and by their characteristic behavior. It is only the buck in the rutting season which exhibits the odor many associate with goats. Due to associative effects of other animals, especially bucks, the anestrus period often will be longer in small isolated flocks of goats. Goats do not routinely exhibit a silent ovulation at the start of the season, and any act, such as introduction of a rutting buck, may cause synchronization of estrus (80). Various types differ markedly in the degree of seasonal restriction. There are insufficient data to attempt to characterize the population in this respect. If sheep may be an example, breeds which evolved and are near the equator are expected to show less response to the photoperiod, and if they do show seasonal restrictions, the explanation may be in other elements of the environment such as feed supply or humidity (58). By contrast, breeds which originated and are located in temperate regions show considerable seasonal response in reproductive activity. In this connection, most of the established dairy breeds show anestrus in February to May. This presents problems to the dairy farmer attempting to produce a year-round supply of milk. The breeding season is sufficiently long to allow at least limited milk production throughout the year, but except for the possibility of endocrine control of reproduction, some seasonality of milk supply is inevitable. Also, those does which kid earlier in the season usually have the best lactation records (93). Asdell (4) and Turner (98) showed the majority of kids were dropped from matings which were in September through December, but some kids were dropped each month of the year. Both these studies utilized herdbook data of the early part of this century, and it is not known to what extent the population has changed in intervening years. Corteel (21) reported data

![FIG. 3. Influence of season on occurrence of estrus.](image-url)
for the French Alpine collected more recently suggesting anestrus in April to June, with February, March, and July as transitional months. The Angora is seasonal (71) and does not show estrus dependably earlier than September. Shelton and Spiller (88) recently have reported seasonality of cycling of the meat-type goat in Texas (Fig. 3), and since this goat is a composite of the non-Angora population, these data may provide an expression of the larger population in the United States.

Length of Estrus Cycle

Reports have been numerous on length of estrus cycle of the goat. These data (15, 80) suggest that most goats of varied types show a cycle of 19 to 21 days. Many workers have observed cycles which differ significantly from this but generally have considered these abnormal and explainable on some basis other than genetic variance in cycle length. Extremes occur when bucks are first introduced into the flock early in the breeding season. Corteeel (22) refers to cycles as short as 8 days and as long as 40 days and suggests these values are normal for certain types of goats. However, this is not supported by observations on any types of goats in this country.

Length of Estrus Period

The length of estrus appears to be highly variable, but this may more nearly represent interpretational differences since estrus is not easily defined. The most commonly stated value is 36 h. Carrera and Butterworth (15) reported 34.4 h with a standard deviation of 8.1 h. Van Rensburg (102) reported 22 h for the Angora breed. For hand mating or A.I. (artificial insemination), many advise checking does for estrus more than once daily as some does in estrus may be missed by once-per-day observation. Ovulation generally is reported as occurring a few hours after the termination of standing estrus. Thus, if a single mating or insemination is to be practical, it should be in late estrus. Insemination may be successful after termination of standing estrus.

The Gestation Period

The gestation period normally is 149 days (81, 102). This appears to be standard throughout most breeds, but Ali et al. (1) reported the mean gestation length in the Black Bengal breed was 143 days. The Black Bengal is one of the smaller breeds of goats, and it is not clear if this shorter gestation is common to all small breeds.

Ovulation and Kidding Rate

Little data on ovulation rate has been reported. Devendra and Burns (27) summarized data relating to kidding rate. In general, except for the Angora, kidding rates are reasonably high for most breeds in good condition with the Anglo Nubian having one of the highest kidding rates of the breeds which are distributed widely. As might be expected, plane of nutrition or degree of development has an important bearing on kidding rate and reproductive success (78, 85).

Some Problem Areas in Goat Reproduction

The seasonal restriction to matings is probably the most frequently incurred problem. This has been reviewed. Also, the relationship of the polled gene to reproduction is a problem in many flocks. This will be reviewed at another section of this paper. The goat appears to be more susceptible to abortion than other species of domestic livestock. The exact explanation for this is not known, but the fact that the goat is a corpus luteum dependent species may predispose the animal to abort when there is an interference with or the absence of a functional corpus luteum. On a world basis, brucellosis (Brucella melitensis) is an important cause of abortion (2). Other infectious agents also can cause abortion (105).

The most serious loss from abortions is for Angora (85, 100, 101, 102). A low level of abortion is common with Angora, and catastrophic losses sometimes occur. The physiological mechanism for this type of abortion is complex, but it appears to be predisposed by competition between the nutritional demands of the fetus and that of fiber production. Most abortions occur in response to stress around 90 to 110 days of gestation. Abortion largely can be eliminated by improved nutrition and management or by selection for an animal which has nutritional requirements more in line with that provided by the environment. Some individuals become habitual aborters, and it may be important to identify and remove these from the flock. If habitual aborters have been
allowed to build up in the flock, the effect will be a high percent of dry, older does in the flock among an age group which should be the most fertile.

Among dairy goats, high producing does often show anestrus or are difficult to settle (23) at the time of peak lactation. This primarily has the effect of increasing kidding interval beyond that desired. Aside from a few well-managed dairy herds, a high proportion of the world’s goat population persists under suboptimal nutritional conditions. Under these conditions, any improvement in nutrition or development will result in a largely linear increase in kid production (78, 84). Nutrients which are specific for reproduction in the goat have not been identified, but the protein requirement for the goat is higher than most species of domestic livestock (86).

Small size of flock (in the U.S. eight head) is often a problem for goat producers. Since some flocks are large, the modal value must be lower than this. As suggested earlier, the small flock can be a factor in length of anestrous period.

Another problem is the cost or inconvenience of keeping a breeding male for this small number and, more importantly, the restriction it places on genetic improvement. Artificial insemination is apparently the only approach to significant genetic progress. From a technological point, A.I. is reasonably successful in goats, but the logistics or costs can present problems with an animal the value of goats. Even so, it may be desirable to keep a male to stimulate ovulation and to identify does in estrus.

The tendency for synchronized matings in female goats often occurs even under field conditions and can present problems in maximizing the utilization of individual males. However, it also may be used to advantage in the management system. The involvement of the central nervous system in reproduction in the goat can be seen in other respects. Producers and researchers alike (82) have observed that stress such as movement to unfamiliar surroundings can prevent or terminate estrus cycling. This is more likely in animals managed under extensive conditions.

For goats raised under extensive conditions, a primary concern of management during kidding is death of kids due to predation, cold stress, or abandonment by does. Any attempt to interfere under extensive conditions usually will increase kid losses. These problems can be overcome by intensification of management, but this often is contraindicated for economy.

**Artificial Insemination of Goats**

The small size of many goat flocks makes it difficult effectively to implement improvement programs, and in some cases it is difficult to justify keeping breeding males. Artificial insemination offers one logical solution to this problem, but its use largely has been restricted to the established dairy breeds.

Both fresh (79) and frozen semen can be utilized reasonably effectively in artificial insemination of goats. Since the report of Frazer (34) of successful freezing of semen, its use has become widespread. The essential components of the technique called for sterile skim milk as a diluent, glycerol 6 to 9%, 1.5 to 2 h equilibration, and a slow rate of freezing. More recently it has been shown that an enzyme in seminal plasma reacts with constituents of egg yolk to produce a product which is toxic to sperm. Seminal plasma itself has been identified as a limiting factor in the freezability of goat semen (21). This can be overcome by washing the sperm cells to remove the plasma before freezing, but this may be difficult to implement in practice. Many stations have frozen goat semen by the same techniques as those for cattle but with variable results. An apparently important requirement for success is the ability for uterine or deep cervical insemination. This can be accomplished more successfully with goats than with sheep and with goats can be accomplished more easily with multiparous as compared to primiparous does. Dilution rates have ranged from 1:1 to 1:50, but higher dilutions have reduced results (51). Dilution 1:5 often will provide less than 100,000,000 cells in .2 cm³ inseminate and is not recommended. With frozen semen, synchronized matings, or with high producing does, an increased number of sperm is recommended. Lunca (51) obtained 70% conception based on a single insemination with fresh semen. Bonfert (9) suggested conception in the range of 60% with frozen semen, and Tsakalof et al. (97) suggested values ranging from 53 to 60% depending on type of extender. Corteel et al. (23) obtained rates ranging from 22 to 50% when frozen semen was combined.
with estrus synchronization. These same workers obtained a lower conception rate from higher producing does.

The Use of Exotic Hormones to Stimulate Reproduction in the Goat

The use of hormonal therapy to stimulate elevated or out-of-season reproduction in the goat is not practiced commercially to any extent. The primary interest would be to control mating in the dairy goat in advance of the breeding season to provide for a year-round milk supply. On a routine basis there appears to be no interest in artificially inducing ovulation in the Angora or meat-type goats. However, Moore (62) has utilized this procedure to facilitate ovum transfer as a potential means of enhancing genetic progress with the Angora in Australia.

Extensive work with sheep has shown that a period of preconditioning by progesterone followed by the use of pregnant mare serum gonadotrophin (PMSG) provides synchronization between estrus and ovulation. Valacos (99) synchronized does by intravaginal suppositories containing a synthetic progestin (M.A.P.) followed by 300 IU of PMSG with a conception rate of 72.5% and 57.0% from multiple inseminations with fresh and frozen inseminations, respectively. French workers (21, 23) used sponges containing 40 to 45 mg flurogestone acetate for 21 days followed by 400 IU of PMSG and obtained conception rates ranging from 22 to 70%. This work showed better results with fresh as compared to frozen semen and better results during the breeding season as compared to out-of-season breeding. Also, high producing does were harder to settle than those producing less milk. The depression in conception rate for the higher producing does largely could be overcome by using a larger number of sperm. Thus, it appears that synchronization and endocrine control of ovulation is possible with this species. However, synchronization agents in these studies are not commercially available to producers in this country.

Pregnancy Diagnosis

A practical method of early pregnancy diagnosis would be helpful to the goat producer. Research has been extensive on methods of pregnancy diagnosis in sheep, and most of the techniques for sheep apply equally as well or better for the goat. The potentially useful producers include radiography, plasma progesterone (21), ultrasonics or doppler principle (40), laparotomy (92), recto-abdominal palpation (44), and ballottement. The latter can be utilized only in the latter stages of pregnancy. Progesterone in plasma requires laboratory procedures not generally available to producers. The ultrasonic procedure is effective as early as 50 days but requires expensive equipment. The recto-abdominal palpation requires that the animal be about 70 days pregnant. Therefore, none of these procedures is totally satisfactory to the producer. Another possible method is based on the development of antibodies to the embryo which has the potential of being utilized before the subsequent estrual cycle. However, the necessary reagents are not available (17). Thus, the only procedure which producers might find useable in routine practice is based on ultrasonics or recto-abdominal palpation, but the latter procedure has caused an occasional abortion (87). During the breeding season, a check for return to estrus is a most valuable practice.

GENETICS OF THE GOAT

A large portion of the world population of approximately 400 million goats is an amorphous collection that is not characterized or categorized easily. However, within this number some well-defined types have been developed or have evolved to serve specific functions or for adaptation to specific production or environmental conditions. In this paper, no attempt has been made to catalog or to discuss the world's population, but mention will be made of a few of the better known breeds which might be of interest in developmental programs with this species.

An attempt has been made to categorize in Table 1 some of the better known breeds by their primary function. In this tabulation, it will be assumed that no goats are developed and maintained primarily for leather production although certain types such as the Red Sokoto and Black Bengal do possess more valuable hides (25). In many countries, goat hides are often more important on a national basis as a source of exchange than they are to the original producer.
<table>
<thead>
<tr>
<th>Type</th>
<th>Breed or genotype</th>
<th>Localization</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy</td>
<td>Saanen</td>
<td>Temperate regions (world-wide)</td>
<td>Guss (41), Colby et al. (20)</td>
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<td></td>
<td>Toggenburg</td>
<td>Europe and U.S.</td>
<td>Guss (41), Colby et al. (20)</td>
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<td></td>
<td>Anglo-Nubian</td>
<td>World-wide</td>
<td>Guss (41), Colby et al. (20)</td>
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<td></td>
<td>Alpine</td>
<td>Europe and U.S.</td>
<td>Guss (41), Colby et al. (20)</td>
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<td>La Mancha</td>
<td>U.S.</td>
<td>Guss (41), Colby et al. (20)</td>
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<td>Meat and milk</td>
<td>Nubian</td>
<td>Sudan</td>
<td>Devendra (26)</td>
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<td></td>
<td>Damascus (Shami)</td>
<td>Syria and adjoining areas</td>
<td>Choweiri (18)</td>
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<td></td>
<td>Jamnapari</td>
<td>India and Pakistan</td>
<td>Singh and Singh (89)</td>
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<td></td>
<td>Barbari</td>
<td>India and Pakistan</td>
<td>Mittal and Pandey (61)</td>
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<td>Meat</td>
<td>Boer</td>
<td>South Africa</td>
<td>Skinner (91)</td>
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<td>Spanish</td>
<td>U.S. and Mexico</td>
<td>Shelton (87)</td>
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<tr>
<td>Fiber</td>
<td>Angora</td>
<td>Turkey, South Africa, U.S.</td>
<td>Shelton (87)</td>
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<td>Cashmere</td>
<td>Asia (China, Mongolia, Iran, Afghanistan)</td>
<td>Burns et al. (11)</td>
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<td></td>
<td>Don</td>
<td>U.S.S.R.</td>
<td>Misharev et al. (59)</td>
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<tr>
<td>Laboratory and pet</td>
<td>Pygmy</td>
<td>U.S.</td>
<td>Hoversland et al. (43)</td>
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aNo interference is implied or intended that this listing is complete or inclusive, but only represents a few of the recognized breed groups by primary function.
The Saanen goats derived their name from the Saanen Valley in Canton Berne, Switzerland. In the 1890's several thousand head were taken out of this valley and spread throughout Europe. The Saanen is one of the largest of all the Swiss breeds. Adult does weigh 64 kg or more and stand from 75 cm at the withers (point of shoulders). Bucks are much heavier and are at least 90 cm at withers. The hair is white or cream in color while the skin beneath usually is mottled. The ears are erect and alert; the nose is straight or dished slightly. Both bucks and does may have beards, but the bucks have a fuller one. Saanens have been acclaimed widely for their milking ability.

Toggenburg dairy goats also originated in the Swiss Alps and are the oldest officially recognized breed of dairy goats. Adult does weigh 56 to 90 kg. They tend to be alert and excitable, shorter and more compact than the other breeds, are angular, and show a lot of width and depth. The ears are erect, the muzzle deep and wide, while the nose is dished. Beards are common. The color is a shade of brown with white lining on the ears, white facial stripes, white legs, and white triangle at the base of the tail. Toggenburg does have consistently good udders, and many of them can milk 2 yr without being bred.

The Alpine goats originated in the French Alps and have since been transplanted to many places in the world. The average does should weigh a minimum of 55 kg. Large, rangy, and angular, the French Alpine is deerlike in appearance. The eye is alert, ears are erect, and the nose is usually straight. Unlike Saanens and Toggenburgs, the Alpine comes in a wide variety of colors and patterns which have French names: Cou Blanc, white frontquarters and blackish hindquarters with black or grey markings on the head; Cou Clair, same as the cou blanc except the frontquarters are tan or saffron; Chamoisee, a blackish or brownish body with black feet and legs, a black dorsal stripe, and often a black face; Cou Noir, the opposite of the cou blanc, with frontquarters black and hindquarters white; Sundgau, black with Toggenburg markings; Pied, spotted.

Nubian goats, as the name implies, are of North African origin. However, the more common type referred to as the Anglo Nubian had its origin in Great Britain when domestic stock and goats of Swiss origin were mated to bucks imported from Africa and India. Through selective breeding the modern Anglo Nubian was produced. Nubians in America today all trace to English imports. The Nubian looks different from all other breeds, having short, sleek hair, long drooping ears, and a Roman nose. The Nubian normally does not give as much milk as the Swiss breeds; however, it is of the highest butterfat content. The average mature doe will weigh 64 kg or more and usually tends to be meatier than the Swiss breeds. Colors are widely varied and include a uniquely spotted type similar to the Appaloosa horse.

The American La Mancha is the youngest breed and the only totally American breed in existence today, with the registry started in 1959. Short-eared Spanish goats living in herds on the West Coast were bred to top sires of other breeds in the '20's and '30's. The original breeders envisioned a thrifty milk goat, compact like the Toggenburg, but very broad in the chest with deep open ribbing. The head should be broad with a powerful muzzle, flat face, and "gopher ears" - nonexistent or very short.

Damascus is a large reddish-colored goat with long ears and Roman nose with various subtypes ranging from North America through the Middle East into Asia. This is no doubt the progenitor or relation of the Nubian. The best known of the subtypes is the Damascus or Shami as found in the countries of Lebanon, Syria, Jordan, and Iraq. A similar goat in Iran is known as the Najdi. Apparently, the Egyptian Zariby is of similar origin, and both show similarity to the Jamnapari of India. Thus, this type is likely the most widespread of the types used largely for milk production. They tend to be concentrated around population centers where they are used as a dairy animal and are not widespread under desert conditions. Milk production under indigenous conditions does not equate with established dairy breeds of temperate regions, but they adapt much better to conditions in areas where they are maintained. Weights range up to 80 kg for bucks and 60 kg for does.

Perhaps the breed which has received the most development for meat production is the Boer goat of South Africa. A goat which has been referred to as the Boer goat has been in the Republic of South Africa for over a century, but the goat has been improved in recent years. It originated from crossing of Nubian or
Indian goats on the Bantu or Hottentots stock. They tend to show the Roman nose and long ears of the Nubian. The animal is large, weighing up to 90 kg for bucks and 60 kg for does. Most have white bodies and red or black head or forequarters but also may be of mixed colors. They reportedly excel common goats of Africa in both growth and reproduction, and they also may be used for milk production.

The term Spanish goat is used in the Southwestern U.S. to refer to a goat maintained primarily for meat production from brush or browse on ranges of the Edwards Plateau of Texas. The term is used primarily to distinguish the animal from Angora or milk-type goats which may be encountered in the region. The name infers that the goats arrived in the U.S. through Mexico, which is not necessarily true in all cases. Most carry at least some influence of dairy breeding, primarily Nubian or Toggenburg. They are highly variable in appearance and performance. Some producers have practiced positive selection for size, conformation, and occasionally color, but most have evolved by natural selection; as a result, they are a highly variable lot in both appearance and performance.

The pygmy goat recently has become recognized as a breed in the U.S., but pygmy-type goats are also under production conditions in Africa and Asia. As implied in the name, this goat is distinguished primarily by its small size (45 to 50 cm high, weighing up to 25 kg). They primarily serve a function in the U.S. as a laboratory ruminant or as a pet, but, they do produce both meat and milk. The goat apparently originated in Africa, where it makes an important contribution to meeting human needs. It may be known by the name miniature goat, West Africa dwarf, African pygmy, or Cameroon goat (43). The animal is normal in appearance except for its small size which appears to rule out its being a simple achondroplastic dwarf. Under some specific conditions, the small size apparently offered an adaptive advantage.

The Jamnapari goat is in India and Pakistan where it serves the dual function of meat and milk production. It is characterized by varied color, Roman nose, and extremely long ears. Its long legs are a noted characteristic of this animal. Similar long-legged types are also in Africa and South America. Those in South America, especially Northeast Brazil, are known as the Buhj but are considered to have resulted from imports from India. The relationship between the Jamnapari and the African long-legged goat is not known. An adaptive advantage for the long legs can be visualized for a browsing animal.

The Angora, Cashmere, and Don are all breeds which are maintained with emphasis on fiber production. The Angora, of Turkish origin, is now in substantial numbers in Turkey, U.S. (Texas), and South Africa. It is the world's most efficient producer of animal fibers and in this country serves no other purpose except for the salvage of cull animals for meat. The Cashmere (China, Mongolia, Iran, and Afghanistan) and the Don (U.S.S.R.) may serve in meat, milk, and fiber production. The type of fiber harvested from these is the fine down type of fiber produced by the secondary follicles in an animal with a dual coat. In the Angora, the fiber produced by the secondary follicles has been developed to the extent that the fiber produced by the primary follicles tends to be masked.

Breed Comparisons for Milk Production

Few data are available for direct comparison of breeds. Geerts (38) summarized the performance of does of the five major dairy breeds which qualified for advanced registry (Fig. 4). In this comparison, the Saanen, Toggenburg, and Alpine appeared to be similar in the amount of milk produced and fat percentage (ca. 3.5%). The Nubians and La Mancha appeared to be distinctly lower in total milk yield. The Nubian tended to run almost 1% higher in butterfat (ca. 4.5%) whereas the La Mancha was only marginally above the other breeds in percent fat. It seems likely that these fat percentages are low since only the higher-producing animals were included in the analyses, and the percent fat in the milk tends to vary inversely with total milk production. Knowles and Watkins (46) tabulated some breed comparisons under English conditions. In these data, the lactation yield (kg) and fat yield (%) were: Saanen (1188, 4.0), Alpine (1136, 4.2), Toggenburg (1087, 4.5), and Nubian (839, 5.6). Fat percentages are higher than those cited earlier.

The above data tend to suggest milk production of 600 to 1200 kg per lactation. However,
under field conditions, this production is not likely except with the established dairy breeds under good conditions. Trodahl (96) reported average milk yields of 560 kg with 3.38% fat for 330 flocks in Norway. Garcia, Castillo, and Gado (37) reported lactation yields under Venezuelan conditions: Nubian 155 kg, Toggenburg 283 kg, Saanen 294 kg, and Alpine 232 kg. Gill and Dev (39) reported lactation yields of 311 and 290 kg for Alpine and Nubian goats under Indian conditions. Bhatnagar et al. (6) reported lactation yields of 124 kg and 184 kg for Beetal and Alpine goats. Louca et al. (50) reported lactation yields of 520 kg for Damascus goats under Cyprus conditions. Since most of these data come from experimental flocks, they are no doubt above that likely to be experienced under field conditions in tropical regions. Some of the recorded production averages are summarized in Table 2.

Estimates of Genetic Parameters

Although few genetic studies have been reported for the goat, the principles of inheritance have been worked out reasonably well with other species, and it is unlikely that these differ significantly for the goat. Thus, implementation of effective selection programs need not nor should not await more complete information. In breeding for milk production of goats, one naturally would draw an analogy with dairy cattle, which have received considerable attention. Goat breeders should have a substantial advantage in a higher reproduction rate and shorter generation interval. Matched against these are the disadvantages of small flock size and less valuable animals which complicate the implementation of herd testing and sire evaluation schemes and effective use of A.I. The fact that selection for milk production can be made effective based on present knowledge is verified by the excellent breeds of dairy goats and their relatively high milk production. On a body weight basis these tend to produce at least comparable to the better dairy cattle. As with dairy cattle, the better dairy breeds originated in the temperate climates, and there is a real need for developmental work under tropical climates. Selection for growth rate and meat qualities in goats has not been widespread even though both can be measured in the growing male. With the possible exception of the Boer goat, most have slow growth rates, low dressing percent, and a low meat to bone ratio with a large part of the fat deposited internally (65, 74, 89). Selection for fiber production, with the Angora as a prime example, can be highly effective (36).

Heritabilities have been reported for most traits for goats. Some of these estimates are summarized in Table 3. These data suggest that the desirable traits for goats are at least moderately high in heritability and closely approach that expected from work with other species. Perhaps the most extensive study of heritability of milk production is that reported by Ronningen (77), which involves national production data from Norway as collected for the Norwegian Dairy Herd Recording Associations for 1963 and 1964. These data show heritability of dairy traits to be on the order of .3. Bouillon and Ricordeau (10) working with Alpine show values up to .6. The reports of Ronningen (77) conform well to values calculated in a similar way for dairy cattle, as reported by Van Vleck and Bradford (103) and Butcher and Freeman (12, 13). Although estimates of phenotypic or genotypic variance are not reported often, observations suggest the goat population in general, and to a lesser extent individual breeds, are highly variable and should give good response to selection. However, in selection for a multiplicity of traits or multipurpose animal, some consideration should be given to the correlation among the traits. Estimates of phenotypic or genotypic correlations are limited and are totally unavailable for comparing such diverse traits as milk and fiber production since the same
TABLE 2. Lactation yields by breeds and location.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Current world record</th>
<th>England&lt;sup&gt;a&lt;/sup&gt;</th>
<th>U.S.&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Venezuela&lt;sup&gt;c&lt;/sup&gt;</th>
<th>India&lt;sup&gt;d&lt;/sup&gt;</th>
<th>India&lt;sup&gt;e&lt;/sup&gt;</th>
<th>India&lt;sup&gt;f&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kg)</td>
<td>(kg)</td>
<td>(kg)</td>
<td>(%)</td>
<td>milk</td>
<td>milk</td>
<td>milk</td>
</tr>
<tr>
<td>Saanen</td>
<td>3430</td>
<td>1188</td>
<td>979</td>
<td>294.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpine</td>
<td>2194</td>
<td>1136</td>
<td>970</td>
<td>232.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toggenburg</td>
<td>2613</td>
<td>1087</td>
<td>921</td>
<td>283.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nubian</td>
<td>2009</td>
<td>839</td>
<td>817</td>
<td>154.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Mancha</td>
<td>1482</td>
<td>835</td>
<td>835</td>
<td>289.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damascus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beetal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>124.0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Knowles and Watkins (46).
<sup>b</sup>Dickinson and King (29).
<sup>c</sup>Garcia et al. (37).
<sup>d</sup>Gill and Dev (39).
<sup>e</sup>Bhatnagar et al. (6).
<sup>f</sup>Louca et al. (50).
population of animals is not used often for both purposes. Although statistical data on these parameters are limited, observation and analogy should provide a reasonable basis for decision making in this respect. The traits of primary interest might be outlined as 1) adaptability to environmental and production conditions, 2) reproductive efficiency, 3) growth rate, 4) carcass value, 5) milk yield, 6) fat percent, 7) fat yield, and 8) fiber production. In addition to these performance traits, individuals or breeders may be concerned with many traits such as head type, body conformation, udder shape, temperament, and anatomical soundness.

Total milk production is correlated negatively phenotypically with percent of fat and protein but is correlated positively with total fat or total protein (73). Thus, if composition of milk is important for reasons such as cheese making, selection must encompass both total lactation yield as well as composition of the milk. Body weight tends to be correlated positively with lactation yield (73). There is reason to believe that high fiber production is correlated negatively genetically with milk production, as well as fertility and growth (85). As suggested earlier, there is little reason to try to develop a combined milk and fiber producing goat. Thus, the negative relationship of these traits should not be a problem. However, the conflict in fiber production and reproduction is a serious one. Adaptability to the nutritional and environmental conditions under which a large part of the world’s goat population is grown almost certainly related negatively to a high growth and milk or hair production but not necessarily reproductive rate. Thus, important genetic-environmental interactions must be kept in mind in developmental programs with this species. Natural selection under the conditions of nutritional stress of arid regions tends to result in small, hardy animals with a good reproductive rate when conditions permit (19). This type of animal is similar to the usual description of a dam breed and should fit well into a scheme for improved meat production if a superior sire breed were available. A sire breed with improved growth and carcass traits is apparently a real deficiency in efforts to maximize meat production from goats.

Mendelian or Qualitative Traits

Although the manner of inheritance has not
been worked out on all of them, a number of
discrete or qualitative traits have been identi-
fied in the goat population. The best known of
these is horns and the associated intersex prob-
lems. Others include color, presence of wattles,
blood types, a type of hereditary paralysis, an
abnormal chromosome structure known as cen-
tric fusion (69), cryptorchidism (53, 104), and
in the case of the Angora goat, an abnormal
type of fiber (87).

Numerous papers have been written concern-
ing the problem of intersexes in goats (4, 31,
42, 96). The situation appears to be that the
polled condition in goats acts as a simple domi-
nant to horns. However, a secondary effect of
the polled gene is the occurrence of intersexes
resulting from masculinization of females and a
sterility problem in the males (30, 74). Appar-
etly, these defects represent a pleiotropic ef-
fact of the polled gene with incomplete pene-
trance. Ricordeau et al. (74) estimated the
penetrance of the male sterility problem as .55.
If this is true, it is restricted to the homozygous
polled individual which it generally appears to
be. However, since the homozygous polled ani-
mal cannot be identified phenotypically, its use
in the breeding program is difficult. In any case,
the problem is real with goat breeders. Most
producers prefer animals without horns, espe-
cially for the dairy breeds, which often are kept
in close proximity to the household. Some
societies have recognized only the polled animal
as suitable for registry, thus imposing a form of
"herdbook heterozygosis." There is some sug-
gestion (48) that the polled gene can act in the
homozygous state as sublethal, since there is a
deficiency of females even when intersexes are
included as females. At present, there appears
to be a trend away from emphasis on genetic re-
moval of the horns in favor of dehorning of
breeding males. A high percent of polled ani-
imals can be maintained in the flock without in-
curring serious intersex problems if a breeding
program is developed to maintain a high
degree of heterozygosity. Alternating the use of
horned and polled sires is one means of accom-
plishing this. The exact manner of inheritance
of cryptorchidism in goats is not known, but
Lush et al. (53) concluded that the genes in-
volved were recessive in nature and few in num-
ber. It seems likely that these authors were
dealing with a case of incomplete penetrance.

Color in goats is highly inherited, but no ser-
ious efforts have been made to identify the
manner of inheritance. Breeders have had good
success in establishing desired color patterns
when these attempts have been made. The
white of the Angora and Saanen is known to
act largely as a dominant, suggesting the action
of an inhibitor gene (49). Blood typing in goats
and the mode of inheritance has been studied
(33, 66), but the results are incomplete and a
detailed review will not be attempted at this
point. The phylogenetic origin and mode of in-
heritance appears to be qualitative. If due to a
single gene pair, it appears to act as a dominant
(87). This is the reported mode of inheritance
of wattles in sheep (8). The gene frequency for
wattles in Angoras is low or near zero. One
flock of Spanish goats exhibited a gene fre-
quency of .2 for wattles whereas in some dairy
breeds, most possess wattles.

A hereditary type of nervous paralysis
(myotonia) in goats has been known since the
early part of this century (52), but the exact
mode of its inheritance is not known. This con-
dition is not a problem to the industry and at
times has been considered an advantage in
handling of wild animals. Ear length in the goat
is inherited in a qualitative manner, as with the
long ear of the Jamnapari and the short ear of
the La Mancha. However, if only one loci is in-
volved, more than two alleles are involved as
ture breeding types for intermediate ear lengths
exist.

Mating Systems

A large portion of the world's goat popula-
tion is maintained under free ranging conditions
in which controlled matings are not possible.
Thus, the mating system may approach random
mating. However, to the extent that only one
breed is prevalent in a general area, it also might
be considered as purebreeding. The amount of
inbreeding which occurs would be largely a
function of size of the population. True cross-
breeding would be possible only if controlled
matings were possible with distinct types. Ex-
tensive use of crossbreeding could be practical
only with the dairy goats, in that with other
types only a single genotype is often available,
as with the Angora for mohair production.
Under production conditions of the U.S.,
crosses between the Angora and meat-type
goats often occur, but more by accident than
intent, as the result is a serious disruption to the primary function of both types and should be avoided. Soviet workers (59, 64) have often crossed the Angora with other fiber-producing types in that country. For the most part, these crosses have been initial steps in creation of new types and not to exploit the phenomenon of heterozygosis. The results of the initial crosses appear to be intermediate in type of fiber produced, much as might be expected.

Crosses between the established dairy breeds are both feasible and are used to substantial degree in commercial practice. However, research verification of the results of these crosses is limited. It seems safe to draw analogy with the extensive experience from other breeds or species and suggest that crossbreeding should prove beneficial in reproduction, growth, and lactation. More importantly, one would be concerned about the results of crossing the established dairy breeds on unimproved or nondairy types as an initial step in the grading up process. Data of this type are also limited, but good results would be expected, subject to the problem of lack of adaptability of the improved dairy breeds to tropical conditions. Also, grading to a very high degree to a breed, such as the Saanen, can present problems. The Nubian tends to be more popular for crossing (16), especially when meat production is one of the goals.

Selection Practices

The analysis made by Geerts (38) suggests that milk production among the U.S. dairy goat population is not increasing. The same may be said for meat production. Selection for fiber production in the Angora is accomplished relatively easily, and time trends in fleece weights support this (56). The limited progress in breeding for milk production, if true, may be explained by the small flock size of much of the U.S. milk goat population and the fact that many of these are hobby-type flocks in which market milk production may not appear important to the individual producer. Also, with an expanding dairy goat population, little culling of does is practical. However, surplus animals produced by these flocks enter trade channels and make up a significant part of the breed structure. Thus, these breeders, and especially the registered breeders, should take their breeding programs seriously since their surplus animals often are sold on an international market. This appears to be especially true with the Nubian breed, which is often in demand for other qualities, but which appears to be lacking in milk production. Small flock size places constraints on genetic improvement due to the small numbers available for selection, the difficulty in implementing testing programs, the problem of proving sires when used in only one small flock, and the management problems in extensive use of artificial insemination. Clearly, effective genetic improvement requires the broad-base application of performance recording and sire testing schemes, or the few larger flocks must be relied upon to contribute superior breeding stock. A mechanism for broad-base evaluation programs is in the National Cooperative Dairy Herd Improvement Program (NCDHIP). These programs were reviewed by Dickinson (28) and Powell (70) and should receive attention by the industry. As pointed out by these authors, the use of sires in more than one herd through the use of artificial insemination is a requirement for effective sire evaluation. The relative costs of these programs to the goat industry likely will be greater than for cattle, but they should, nevertheless, be given serious consideration by those who are to make an effort at breed improvement. In addition to merely recording milk or fat production, it appears that visual evaluation of the udder should receive some attention.

Selection for improvement in meat production in goats certainly deserves attention. The components of efficient meat production are fertility or reproductive rate, growth rate, and carcass value. Goats appear to have benefited from man's neglect in respect to fertility in that as a species they no doubt have the highest reproduction rate of competing ruminant species. There is good reason to believe that with other species, selection for such traits as visual conformation and growth rate has affected reproduction adversely. Thus, in efforts to select for these traits in the goat, it is important that reproductive rate not be neglected, except for possible development of sire breed. At present, it is not clear what action should be taken in breeding for carcass merit in goats. In the absence of additional guidance, a preference should be shown for overall red meat production which would be a function of reproductive
rate, growth rate, and carcass yield.

A clear need in the Angora is to reorient what has been a largely visual selection for fiber production on a high plane of nutrition to place some emphasis on size and fertility under actual production conditions.

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