REVIEW OF LITERATURE

CONTENTS

1. MILK PRODUCTION FROM GOATS

1.1 The Place of Goats in the World Economy 7

1.2 The Value of Goat Milk 9

1.3 A Place for Dairy Goats in Southern Africa 10

2. FACTORS AFFECTING MILK PRODUCTION IN GOATS

2.1 Genetic Factors 12

2.1.1 Breed Differences and Selection

2.1.2 Inbreeding

2.1.3 Crossbreeding

2.1.4 New Genetic Technology

2.2 Physiological Factors 15

2.2.1 Age

2.2.2 Seasonal Influence

2.2.3 Multiple Births

2.2.4 Length of Lactation and Dry Period

2.3 Milking Management 17

2.3.1 The Use of a Milking Machine

2.3.2 Milking Frequency and Milking Intervals

2.4 Fertility Management 18

2.4.1 Breeding Season

2.4.2 The Influence of Male Goats

2.4.3 Age at First Breeding

2.5 Kid Rearing 20

2.5.1 Prolificacy

2.5.2 Kid Survival

2.5.3 Kid Rearing Systems

2.6 Nutrition 22

2.6.1 Nutrient Requirements

2.6.2 Feeding Systems

3. GOAT MEAT PRODUCTION 24

4. DISEASES IN GOATS
4.1 Incidence of Diseases in Goats 25
4.1.1 Infectious Diseases
4.1.2 Coccidiosis
4.1.3 Caprine Arthritis Encephalitis (CAE)
4.1.4 Tick-borne Diseases
4.1.4.1 Heartwater
4.1.4.2 Anaplasmosis
4.1.6 Mastitis
4.1.7 Internal Parasites
4.1.8 Nutritional and Metabolic Diseases
4.1.9 Other Diseases
4.2 Genetics and Disease Resistance 30

5. GOAT MILK PRODUCTION IN RURAL DEVELOPMENT
5.1 The Farmers 31
5.2 The Animals 31
5.3 The Environment 32
5.3.1 Forage Supply
5.3.2 Fertility Management and Breeding
5.3.3 Disease Control
5.3.4 Markets
5.3.5 Support Services
5.4 Economic Factors 34
5.5 Complete Systems 35

1. MILK PRODUCTION FROM GOATS

1.1 The Place of Goats in the World Economy

Goats are kept in most countries of the world and estimates of numbers have been made by such organizations as the FAO (1986). They are kept for meat, hides, fibre and milk production. It was estimated that in 1985 there were 485 million goats, and that goat milk production totalled eight million tonnes. Of the total world population of goats, 94 percent are said to be found in developing countries, supplying 73 percent of the milk produced by goats (Devendra 1987a). Tropical Africa contains one-third of the world's goats, but "they have been neglected politically and scientifically" (Wilson 1988). In most circumstances goats are kept in small herds by poor people and may run with other animals such as sheep or cattle. They contribute a significant amount to the daily welfare of the very poor, even for the 123 million landless poor of India (Devendra 1992a). They are seldom kept for one type of production alone. For example, they may be mainly kept for meat production, but higher-yielding goats may be milked as the opportunity arises on a seasonal basis (Matthewman 1985).

Leather production from goats has become a major industry in India and other Asian countries in recent years (Saithanoo & Naidu 1996). Cashmere production is a significant contributor to small-farmer income, particularly in China (Youzhang 1996). Mohair production is important for commercial farmers (Laker 1996), especially in South Africa (van der Westhuysen *et al.* 1988). However, most production from goats is utilized in the small farm context, where its impact and value is often not measurable (Devendra 1996).

Variability in body size and in geographic distribution among breeds of goats exceeds that of any other farm animal (Shkolnik 1992). Goats are particularly well adapted to hot climates (Singh & Singh 1992). They are often unfairly accused of causing environmental deterioration and even desertification (Singh 1992); but they can form an important part in the ecology of rural areas (Acharya & Singh 1992), and can even be used to control bush encroachment (Allan & Holst 1996; Woldeghebriel *et al.* 1992). Goats are usually not of specific breeds in the formal sense, although many types can be distinguished. Some have a greater potential for milk production and are known to be kept primarily for this purpose (Gall 1975).

Goats are usually kept extensively and this may mean that there are severe nutritional constraints on their ability to produce milk. Such constraints may also apply in urban or peri-urban areas where "town goats" are kept under circumstances that are most unfavourable, especially in terms of the adequacy of nutrition. Many different systems of keeping goats occur in different parts of the world, and they may be both appropriate and efficient. However, improvements in productivity may be achieved by simple changes in methods of management, nutrition, disease prevention and health care (Mavrogenis & Narjisse 1992). Small holder goat production systems in Africa have been reviewed (Wilson *et al.* 1992).

Milk production from goats is substantial in many countries of Europe such as France (Sigwald & Lequenne 1985; Sopexa 1986), Germany (Geissler 1987), Great Britain (Mowlem 1988), Greece (Hatziminaoglu *et al.* 1982; Katsaounes 1986) the Netherlands (Boogaert 1982), Norway (Nygaard 1986), Spain (Ballester 1986), and Yugoslavia (Antic *et al.* 1986). However even in these countries most people who keep dairy goats keep a few for household use; and the commercial producers, while they may have large numbers of goats in their herds, are relatively few in number .

Goats are also kept for milk production in developed countries elsewhere, such as Australia (Rayner 1985), New Zealand (Horton & Dawson 1987) and the United States of America (Haenlein 1986). They have been reported to be a significant source of milk in many developing countries as well, including Brazil (Neto & Baker 1987), Central America (Stanton 1982), India (Saini & Khan 1986), Israel (Laor 1982), Mexico (Peraza 1986) and Thailand (Sarabol 1985). The difficulties commercial goat producers face include the need to manage successfully the whole spectrum of production, processing and marketing. This is because there may be no co-operative ventures or State controls over goat milk production, comparable to those that apply to the cow milk industry. Commercial ventures are also faced with problems of organization, inadequate facilities, and in particular, labour requirements, as a result of the large number of goats required to ensure economic viability. In few cases are the dairy goats the sole source of income (Mowlem 1988).

It is apparent that most people who keep dairy goats do so for a household supply of milk, with perhaps a surplus sold locally as milk or cheese. In France there are more than 80 recognised varieties of goat cheese (Le Jaouen 1982).

1.2 The Value of Goat Milk

Goat milk varies in quality in a way similar to that of cow milk (Le Jaouen 1986). For example, composition changes with breed, stage of lactation (Jenness 1980; Loewenstein 1982; Parkash & Jenness 1986), and feeding (Calderon *et al.* 1980; Morand-Fehr, Chilliard & Sauvant 1982; Morand-Fehr & Sauvant 1980). Disease, especially mastitis, can affect milk quality (Park & Humphrey 1986). If milk is produced unhygienically, it will be contaminated (Danielsson *et al.*

1982; Lewis 1988). Mineral content has also been documented (Park & Chukwu 1988). An example of the variability in compositional quality is given in the following Table (after Jenness 1980; Parkash & Jenness 1968):

Country	Breed	Total Solids (%)	Fat (%)	Protein (%)	Lactose(%)
Australia	Saanen	12.24	4.01	3.10	4.93
Germany	Fawn	12.43	3.92	3.52	4.48
India	Barbari	-	4.11	3.76	4.80
Nigeria	Saanen	12.15	3.41	3.07	4.54
Nigeria	Red Sokoto	15.28	4.86	4.38	4.72
Nigeria	Dwarf	17.87	7.10	4.71	5.58
UK	(various)	13.2	4.5	2.9	4.1
USA	(various)	13.5	4.6	3.6	4.7

Comparisons of milk yield should be made in such a way as to take account of compositional quality. A system similar to the Fat Corrected Milk (FCM) procedure for dairy cows may be used (Mavrogenis & Papachristoforou 1988; Van Zyl *et al.* 1988).

Analyses have been made of milk quality in Boergoats (Casey & Van Niekerk 1988), and the mean milkfat and protein analyses were 7.7% and 4.3% respectively. Milk from goats on the milk recording scheme in South Africa and registered with the Breed Society (n=263) had milkfat and protein contents of 3.16% and 2.65% respectively, for lactation yields of 981kg; milk from unregistered goats (n=281) had average analyses of 3.04% and 2.53% respectively for lactation yields of 986kg (RSA 1996). Indigenous goats in first lactations averaged 8.89% milkfat and 5.36% protein, which was three and two times respectively the concentration in milk from Saanens kept under the same circumstances (Donkin *et al.* 1990).

Goat milk differs from cow milk in the amino acid content and composition of the proteins (Addeo *et al.* 1987; Loewenstein 1982; Quiles *et al.* 1994) and therefore can have particular benefit in diets of children and adults who show sensitivity or allergic reactions to cow milk (Gorney 1982; Maree 1978). This is not to be confused with lactose intolerance reactions (Podleski 1992; Savaiano & Levitt 1987). Park (1994) reviewed the information available concerning the hypo-allergenic and therapeutic significance of goat milk. The incidence of allergy to cow milk in the United States is estimated at about 7% of children. Between 40% and 100% of patients allergic to cow milk proteins have been found to be tolerant to goat milk. Other advantages are the smaller fat globules, higher proportion of short and medium chain fatty acids and softer curd formation which are beneficial for digestibility and healthier lipid metabolism in comparison to cow milk.

Analyses indicate that one particular vitamin, folic acid, is deficient in goat milk (O'Connor 1994). Therefore, for infants relying on goat milk as the sole source of nutrients, a suitable supplement should be given to prevent anaemia (Davidson *et al.* 1984). However there is some evidence of a greater bioavailability of iron in goat milk than in cow milk (Park *et al.* 1986). In conclusion, it is clear that goat milk is a valuable source of nutrients and is in many ways comparable to cow milk. It is a potential resource that should be utilized.

1.3 A Place for Dairy Goats in Southern Africa

In Southern Africa goats are kept primarily for meat production (Donkin 1988) or for mohair production (Van der Westhuysen *et al.* 1988), and they are not a significant source of milk. There are probably only two or three thousand dairy goats of the recognised European breeds (Donkin 1988).

In any developing country a major problem is always posed by the rapid increase of the population and the large proportion of people with small incomes. Improved medical facilities and primary health care reduce infant mortality and there is a massive increase in the proportion of children in the society, as the parents still have large families. Mothers may reduce breast-feeding which can lead to a shorter interval between pregnancies (Morley & Lovel 1986). Very often the children are malnourished. This may be as a result of lack of food in sufficient quantity, or as a result of a lack of good quality food, or both, and has long-term consequences (Scrimshaw 1990). Milk is an ideal supplement to reduce any malnutrition (Davidson *et al.* 1984; Maletnlema 1987).

Families may not be able to buy fresh milk or milk powder because of the cost or because it is not available. The obvious solution for people in rural areas is for them to increase milk production from animals that are already available. Dairy cows, as the traditional source of milk, are expensive, require sophisticated feeding and management to be productive, and may produce more milk than required for the household. Beef cattle may be milked for the benefit of their owners (Tapson 1990), but yields are often so low that this will be to the detriment of the calf. In addition, fertility levels may be such that a calf is born only every two or three years, and milk is only sporadically available. The average livestock owner may keep very few cattle (Bembridge 1987). A study in Kenya has shown that the introduction of dairy cows was only feasible when farmers had access to credit and health and nutrition technology, and that cows were not desirable for smallholder farmers (Stotz 1982). In contrast, dairy goats are more appropriate to the needs of subsistence production and their use would be in harmony with the concept of the household economy (Low 1986). Goats are cheaper; require less food; produce appropriate quantities of milk; breed at a younger age; have multiple births; are more easily handled by women and children; represent a smaller loss in the event of death; and produce a carcase of appropriate size for a household's needs (Devendra & Burns 1983).

There is great potential for development of milk production from goats in the tropics (Sands & McDowell 1978), and in Southern Africa as well (Donkin 1988). Projects for this purpose have already been established in recent years in Kenya (Boor *et al.* 1987; Kitivo *et al.* 1982) and in Zimbabwe (Harrison 1988). In Kenya, Miller and Mwangi (1996) have reported the difficulties and benefits of goat milk production monitored with 1300 farmers. In Malawi, research projects have been concerned with evaluating milk production from indigenous goats (Cooper *et al.* 1994) and crossbred goats (Boylan *et al.* 1996). In Botswana, a survey has indicated that goat numbers have increased from 557 000 to over 2 million between 1979 and 1990. Goats are kept for milk as well as meat (Mrema & Rannobe 1996), even though milk production is only about 400ml/day (Mrema 1996).

2. FACTORS AFFECTING MILK PRODUCTION IN GOATS

2.1 Genetic Factors

2.1.1 Breed Differences and Selection

Some indication of breed differences has already been given in Section 1.2 (above). European breeds of dairy goats generally have a far higher potential for milk production than indigenous breeds that have not been selected for this attribute. This difference applies even when account is taken of the generally higher solids content of the milk of indigenous goats.

In countries such as France (Sopexa 1986) and the USA (Wiggans & Dickinson 1984) dairy goat sires are evaluated in a way similar to that applicable in dairy cattle. However, artificial insemination has been used successfully in goats only in recent years (Sopexa 1986), so that the effect of an outstanding sire is less widespread than for dairy cattle sires (Steine 1982).

A study of genetic parameters for milk production in dairy goats indicates good potential for improvement by selection (Ronningen 1966). Expected genetic gains in milk range from 3.0 to 3.8 percent per annum if a standard deviation of 300kg is assumed (Dentine & McDaniel 1982). Progress is also possible in non-dairy breeds such as the Beetal, although from a much lower initial level of milk production (130kg per lactation) (Singh & Acharya 1982). Unimproved types of goats may have low milk yields of up to 100 to 200kg in lactations of 140 to 180 days (DeGroot *et al.* 1992; Roy *et al.* 1992).

2.1.2 Inbreeding

Inbreeding is generally undesirable for the improvement of many traits because of the effects of homozygosity in allowing the expression of undesirable genes, resulting in inbreeding depression. This is usually greatest for characters associated with natural fitness such as viability and reproductive ability (Nicholas 1987). A general conclusion is that inbreeding should be avoided (De Lange 1989). It is possible that dairy goats in South Africa may be inbred to some degree because of the small population. Inbreeding should be assessed in case it affects productivity. Baker & de Souza Neto (1989) specified inbreeding as one of the main reasons for low productivity of crossbred goats in Brazil.

2.1.3 Crossbreeding

Crossbreeding results in heterosis (hybrid vigour) for certain characteristics. It is apparent when the average performance of crossbred progeny is superior to the average performance of the two parents. If this is a significant effect, the benefits may not persist with subsequent crossings or grading-up (Nicholas 1987). The main dairy goat breeds have been developed in Europe, and their yields generally far exceed those of indigenous breeds in other parts of the world (Mason 1981; Sahni & Chawla 1982). In a number of cases the milk yields of European breeds, such as Saanen, Alpine, Anglo-Nubian and Toggenburg goats, have been depressed to between 20 and 50 percent when they were kept in tropical countries. Such reductions were probably due to poor genetic potential, nutrition, disease or environmental stress (Steinbach 1987). Similar reports were recorded by Sands and McDowell(1978), except for goats in Israel and South Africa, where the environment and management were more favourable (Hofmeyr 1969). Yields of milk recorded goats in South Africa are similar to those of goats in Europe (RSA 1996; Shelton 1978).

Crossbreeding is a logical step to improve milk production of indigenous goats, and has been done in many countries (Galal 1987; Ricordeau 1981). Crossbreeding with European dairy goat breeds has in most cases resulted in large increases of milk production, even where environmental and management factors may not have been ideal. (See Table below: Sahni & Chawla 1982).

Country	Breeding	Milk Yield per Lactation (kg)		
		Native	F1 Crossbred	Three-quarter Bred
Korea	Saanen x Native	91	288	355
Puerto Rico	Saanen x Native	188	245	285
Turkey	Saanen x Kilis	261	710	718
Malaysia	Anglo-Nubian x Kambing Katjang	90	296	-
India	Saanen x Beetal	164	306	372
India	Saanen x Barbari	67	164	-

European dairy goat breeds (Alpine and Saanen) have been found to have lower milkfat and protein than crossbred and Indian Beetal goats. The crossbreds were intermediate in production. Stage of lactation and season had significant effects, even when goats were on uniform diets and systems of management (Bhatnagar *et al.* 1982; Chawla & Verma 1982). Similar results of crossbreeding European dairy goats with local breeds have been demonstrated in Turkey (Ozcan & Gursoy 1982); in Venezuela (Garcia, Bravo, Kennedy & Garcia 1982; Garcia, Garcia, Kennedy & Bravo 1982); in Chile (Hernandez-Naus *et al.* 1987); in China (Pu *et al.* 1987; Shongjia *et al.* 1992); in Malaysia (Mukherjee *et al.* 1985; Stemmer *et al.* 1996); in Mexico (Mellado *et al.* 1991); and Norway (Bakkene 1985). Little benefit of crossbreeding was found in India in an arid environment (Mittal 1992).

Crossbreeding has been carried out with Boergoats as well, in Kenya (Angwenyi & Cartwright 1987) and Germany (Schumacher *et al.* 1982), but mainly with the objective of improving meat production. Other experiments in crossing meat goats have been reported from Tanzania (Das 1992) and India (Panandan *et al.* 1992). Crossbreeding may be practised for a number of reasons, including the benefit of heterosis; as an initial stage of transition in establishing a breed ("grading-up"); or for the development of a new breed. The use of established dairy breeds for this purpose may be particularly relevant in unfavourable environments. Whether up-grading or the development of a new breed is the best policy will depend on the environment and level of management (Shelton 1986). The option of crossbreeding to introduce suitable genetic material for milk production is a much more rapid method than that of attempting to improve milk yield of local goat breeds by selection (Sands & McDowell 1978). The research reported by Rege *et* *al.* (1994) concerning crossbreeding with Jersey cattle in Africa has relevance, as the principles are the same. With Gudali x Jersey cattle, there was no significant advantage in increasing the proportion of Jersey genes beyond 0.5 for milk production traits. Heterotic effects were large and significant in improving milk production in Ghana Shorthorn crosses, although no heterotic effects were significant for reproductive traits. If this research has applicability with milk goats, then a third breeding option of producing first-cross females (F1) for milk production might be appropriate. The Crossbred females could be back-crossed to Indigenous males to produce progeny suitable for slaughter.

2.1.4 New Genetic Technology

Artificial insemination technology is now established for goats and can be expected to be used more widely in future (Greyling 1988). However, the value is limited by the effectiveness of systems for identifying outstanding sires, and by the generally small size of dairy goat herds (Mukherjee 1992). Nevertheless, this may be easier than in the past by using such analytical techniques as BLUP or REML (Hill & Meyer 1988). One recent factor that may inhibit the development of artificial insemination is that there is a risk of transferring Caprine Arthritis Encephalitis Virus (CAEV) in the process (Knowles *et al.* 1987).

Embryo transfers can be carried out in goats (Moore 1987), but are likely to have limited applicability (Foote *et al.* 1987; McKelvey & Bhattacharyya,1992). Ishwar & Memon (1996) have reviewed the technology for embryo transfer. *In vitro* production of embryos has had limited success (Poulin *et al.* 1996). Gene transfer technology (Memon & Ebert 1992) is also unlikely to have practical application for the forseeable future (Armstrong *et al.* 1987).

2.2 Physiological Factors

Many physiological factors can affect milk production, and will have to be assessed in relation to lactation yields measured. Mathematical models of lactation curves are useful to describe the essential characteristics of lactation during the lactation cycle. They can be used for predicting and comparing actual with expected milk production; for analysing data for the effects of factors such as genetic potential, stage of lactation, age and parity (lactation number); and assessing the effects of management, feeding practices and health care.

Wood (1969) established a method of fitting lactation curves for dairy cows. This method has also been used to fit curves to lactation data for East African goats (Wahome *et al.* 1994); for crossbred goats in Kenya (Ruvuna *et al.* 1995) and in Mexico (Montaldo *et al.* 1997); and to Comisana sheep in Italy (Portolano *et al.* 1996), US sheep breeds (Sakul & Boylan 1992), and Merino sheep in South Africa (Groenewald *et al.* 1995). Factors such as breed, season of kidding, lactation number (parity), and number of kids were found to be significant influencing factors. However, the papers of Williams (1993 a,b) critically evaluated the Wood models in comparison with other models proposed by Gipson & Grossman (1989) and Morant & Gnanaskathy (1990). Williams (1993a) indicated that the Wood model was less satisfactory than the Morant model, because it overestimated peak yields, underestimated mid-lactation yields, and over-estimated late lactation yields. In contrast, the linear Morant-4 model was adopted as the method of choice, because it was easy to use, relatively easy to fit, and there was little pattern of residuals after fitting the curves. Groenwald *et al.* (1995) also found the Morant models to be more satisfactory in describing the lactation curves of Merino sheep.

Some of the more important aspects influencing milk production are discussed here:

2.2.1. Age

Age is closely related to body size and parity (lactation number) as it affects milk production (Devendra & Burns l983). Body mass may increase up to six years of age and decrease there-after, and milk yield varies similarly, with peak milk yield at between four and eight years (Gall 1981). Factors can be calculated to adjust lactation records to a Mature Equivalent basis for comparative purposes (Wiggans 1984). However, Browning *et al.* (1995), working with Alpine goats, found the highest yields (960kg) in second lactations, and the lowest (634kg) in seventh lactations.

2.2.2. Seasonal Influence

Season of kidding can affect milk production (Gall 1981) and is often confounded with age effects. Adjustment factors can be calculated to correct for this bias (Wiggans 1984). Extremely cold weather can reduce milk production (Gall 1981; Mourad 1992). Goats producing milk are susceptible to heat stress in spite of heat resistant characteristics (Lu 1989).

2.2.3. Multiple Births

Mammary growth during gestation is said to be affected by the number of kids, and this has a subsequent effect on milk production which is independent of age, bodymass and season (Gall 1981; Mourad 1992). Milk production may also be increased in response to suckling stimuli, but this is not a factor in dairy goats if the kids are taken away and fed by hand (Devendra & Burns 1983). Williams (1993b) found no evidence of an effect of litter size on milk yield. However, Browning *et al.* (1995) found that Alpine does that had given birth to singles had a lower milk production (775kg) than does with twins (834kg) and triplets (903kg). This was despite the removal of kids at birth.

2.2.4. Length of Lactation and Dry Period

Some goat milk producers breed high yielding goats only every second year, to ensure continuity of milk production, with a resulting lactation of up to 22 months. However the more usual practice is to breed them annually, resulting in a lactation of ten months and a dry period of two months. Non-dairy breeds may not have a lactation this long, and then the dry period would be longer than two months (Devendra & Burns 1983). As with dairy cattle, it appears that a dry period is essential before a new lactation, to allow time for regeneration of secretory tissue. Short dry periods reduce subsequent milk yields (Schmidt & Van Vleck 1974). However, one experiment (with only four goats) showed no reduction of milk yield after the dry period was omitted, comparing milk production between halves of the udder (Fowler *et al.* 1991).

2.3. Milking Management

2.3.1. The Use of a Milking Machine

In small herds goats are milked by hand, but when goat numbers increase beyond 30 goats, consideration is given to the use of milking machines (LeJaouen 1981). A vacuum level of 45 to 52 kPa, pulsation ratio of 60:40 and a pulsation rate of 90 pulses/min appear to be optimal for machine milking of goats (Lu *et al.* 1991). Provolo *et al.* (1993) compared milk jars or milk meters for recording milk yields in Italy. They concluded that milk meters were liable to greater errors than milk recording jars, so that sampling had to be more frequent and precise compared to cow recording systems. The milking routine must ensure effective milk-letdown without stress, as adrenalin will reduce milk ejection and inhibit milk production. The structure of the goat mammary gland differs from that of the cow in that the volume of the cistern is greater in relation to total gland volume. This may mean that goats are less dependent on the milk letdown reflex for complete removal of milk than are cows (Gall 1981). Nevertheless, behavioural expression of temperament can be related to differences in the inhibition of milk ejection (Lyons 1989). This may be a factor reducing milk yield in indigenous goats. For example, some breeds of cattle will not show an effective milk ejection reflex without the presence of the calf (Alvarez *et al.* 1980). The release of milk (letdown) has been demonstrated to be important in one experiment with East African goats in Kenya. Milking in the presence of kids increased milk yield. However, as a consequence, too much milk was taken for human use, and there was little residual milk left to sustain adequate growth of the kids (Ruvuna *et al.* 1987).

Studies on milk letdown have been carried out with different breeds of indigenous goats in France (Sinapis *et al.* 1993); in Bulgaria (Ouzunov & Zounev 1993); and the Czech Republic

(Cumlivski & Stoural 1993). They showed that at least 80% of goats had no problems with milk letdown, provided they were adequately stimulated. The conclusion was that machine milking was acceptable for these breeds.

2.3.2. Milking Frequency and Milking Intervals

A reduction in the number of times a goat is milked per day will reduce milk yield. If goats are only milked once a day, then yield will be reduced by one third. If one milking is omitted on Sunday afternoons, yield will be reduced by 5 percent (Mocquot 1985). Secretion rate increases when milk is removed more frequently, as for example with thrice daily milking, especially for those goats that store a relatively high proportion of their milk in the alveoli compared to cisternal volume (Knight *et al.* 1989). It is well known that a greater frequency of milking increases milk production in cows, and conversely, that a build up of milk in the udder will reduce milk yield. Traditionally this was assumed to be a result of a build up of intra-mammary pressure (Schmidt & Van Vleck 1974), but more recent research has indicated that it is the effect of a fraction of whey protein (Wilde & Peaker 1990) which affects the proliferation and loss of secretory cells. Whatever the reason, dairy farmers try to keep the intervals between milkings to similar lengths of time. High-producing cows and heifers have been shown to give four to seven percent less milk if milking intervals were 16 and 8 hours (Bath *et al.* 1985). It is possible that uneven milking intervals will have less effect in goats than in cows (Mowlem 1988), because goats have a greater proportion of cisternal milk than cows (Dewhurst & Knight 1993; 1994). It may be necessary to adjust milk records either for long intervals or for increased milking frequency if these are factors in the management system.

2.4 Fertility Management

The productivity of dairy goats must be seen in the context of management of the whole herd. The effects of management, environment or disease on individual goats can have a wider effect on the efficiency and profitability of the whole herd or enterprise. For example, crossbreeding may affect breeding season, reproductive efficiency and kid mortality. Conversely, management decisions concerning such aspects as age at breeding and feeding strategy could have significant effects on the results obtained from a crossbreeding experiment (Shelton 1978). Some of these aspects will now be discussed.

2.4.1. Breeding Season

Oestrus can occur at any time during the year with most tropical breeds of goats although they may be affected by poor nutrition (Delgadillo & Malpaux 1996), but breeds developed in temperate zones are seasonally polyoestrous (Walkden-Brown & Restall 1996). For both types there is a peak of sexual activity in autumn, associated with decreasing day-length (Devendra & Burns 1983), but often two peaks of activity are shown (Gonzalez-Stagnaro & Madrid-Bury 1982). Season of kidding may affect milk production, with peak production occurring in summer. This could be ascribed to nutritional effects (Kawas *et al.* 1992), but photoperiod is also important (Gall 1981). The effect of photoperiod has been reported by Chemineau (1992); by Chemineau *et al.* (1992); and Chemineau *et al.* (1996). There may be differences between male and female goats in their reaction to photoperiod changes (Debenedeth & Coll 1992).

Problems of marketing may arise if the breeding season is limited, because there will be a time during the year when the goats are in their dry period before the subsequent lactation. Manipulation of the lighting system can be an effective mechanism for inducing year-round breeding in dairy goats (Ashbrook 1982), and melatonin can be used to augment this method (Deveson *et al.* 1989). Other hormonal treatments have also been shown to be effective (Amoah & Gelaye 1990; Corteel *et al.* 1988; Holtz & Sohnrey 1992; Pendleton *et al.* 1992).

2.4.2 The Influence of Male Goats

The male goat is generally fertile if free from inherited defects, but a physical examination and assessment of the semen is desirable (Smith,M.C., 1992). Spermatogenesis in Black Bengal goats started at 4.5 months and was completed one month later (Majumdar 1992). Polled billy goats will produce hermaphrodite kids, and so horned males should always be used (Ricordeau 1981; Margetin 1992). The "male effect" can be used to synchronize oestrus, resulting from multisensorial, but mainly odour stimulation (Restall 1992); or in combination with other treatments such as light (Delgadillo & Malpaux 1996). Seasonality can be significant in male goats (Roca *et al.* 1991), but this can be successfully minimized by the use of photoperiodic cycles (Delgadillo *et al.* 1992). However, experiments in Mexico with does in either poor or good body condition, showed no benefit of stimulation with male goats prior to breeding (Mellado *et al.* 1994). Artificial insemination is used successfully in some countries (Leboeuf 1992; Mowlem 1992).

2.4.3 Age at First Breeding

If goat kids have grown well enough then they should be ready for breeding at seven or eight months of age, and will begin the first lactation at 12 months. However, in many circumstances kids will not be ready until they are 18 months old, and they will then give birth at two years of age (Chawla & Bhatnagar 1982). This wide variation is partly genetic and partly environmental in origin (Devendra & Burns 1983). Target mass before breeding will differ depending on the breed, and examples are 18 to 20 kg for the Katjang goat in Malaysia (Devendra & Burns 1983);

and 32 kg for dairy goats in France (Morand-Fehr, Hervieu, Bas & Sauvant 1982). The non-developed tropical breeds are said not to show much diversity from developed temperate breeds in age at first kidding (Aboul-Naga & Hanrahan 1992).

2.5 Kid Rearing

The number of kids born, kid mortality, system of rearing and incidence of diseases can affect growth rate and therefore breeding age. This in turn affects the number of young females entering the milking herd (to ensure continuity of production), and the level of milk production expected. Such parameters are affected by genetic (breeding) and environmental (management) policies and practices.

2.5.1 Prolificacy

Devendra and Burns (1983) have listed expected litter sizes for a wide variety of breeds of goats, ranging from 1.0 to 2.3. These statistics may sometimes become confused where goats are bred to give more than one litter a year (Ricordeau 1981). Some of the differences may be genetic, but age, bodymass and condition can also influence litter size (Constantinou 1989; Teh & Escobar 1987). One study showed year effects, but no influence of season of kidding or sire (Prakash & Khan 1987). The heritability of litter size is said to be low (Ricordeau 1981).

2.5.2 Kid Survival

Mortality among kids is a major factor determining the productivity of a herd (Sherman 1987). Neonatal deaths always make up a high proportion of total mortality, and may be caused by dystocia, cold, lack of food, and diseases (Devendra & Burns 1983). The influence of diseases, especially coccidiosis, is discussed elsewhere.

Differences in placentation can affect the growth and viability of lambs, and it would be reasonable to suppose that this would also apply in goats (McDonald *et al.* 1981). *In utero* infections can cause abortions and weak kids (Lefevre 1987b). Respiratory diseases (Ojo 1987) and gastrointestinal disease (Nagy *et al.* 1987) are major causes of kid mortality.

Kid survival has been shown to be dependent on birthmass. For example, a high mortality was shown by feral Australian kids of less than 2.5 kg, and poor nutrition of does resulted in a kid survival rate of 64 percent compared to 86 percent for those that were better fed (Bajhau & Kennedy 1990). Another study has shown that kids dying within 48h of birth were significantly lighter (2.3kg) than those that survived (2.9kg) (Allan, Holst & Hinch 1992). Up to 68% of peri-natal mortality was due to starvation (Allan, Hinch & Holst 1992). Birth weight, and not genetic factors, has been identified as the main determinant of kid survival in India, which were 79% from 3 to 6 months, and 82% from 6 to 12 months (Singh *et al.* 1991).

Immunoglobulin levels that result from adequate ingestion of colostrum are important (O'Brien & Sherman 1993a,b). Vihan (1988) has observed a 20% mortality in deprived kids, and reported the beneficial effects of vaccination with *E. coli* vaccine in prevention of colibacillosis (Vihan 1993). Artificial rearing of goat kids using an early-weaning (four week) system in England resulted in mortality of 33% post-weaning from starvation, compared to low levels when kids were weaned at eight weeks (Owen & de Paiva 1982).

Kid mortality has been reported to be higher for dairy goats (41.1 %) than for other breeds (average 33.8%) in India (Khera & Harbola 1982). Other reports indicated lower mortalities than these (approximately five percent), especially in extensive systems (Misra & Acharya 1987). In contrast, in Venezuela, mortalities of crossbred goats (European dairy goats crossed with native goats) varied from 26.5 to 47.5%, with no particular breed differences apparent (Garcia, Garcia, Kennedy & Bravo 1982). In Haiti, mortality of crossbred kids was lower (28%) than that of purebred Haitian kids (43%)(Martinez *et al.* 1992).

Mortality of Red Sokoto goats in Nigeria was 22.8% within the first month, due to abortion, dystocia, pneumonia, "starvation complex", *Haemonchus*, ectoparasites and predation. The major causes were pneumonia and "starvation complex", resulting from poor mothering ability (Ojo 1996). In Zimbabwe, pre-weaning losses of kids on communal grazing have been reported to be high (Ndlovu & Sibanda 1991). A further report from Zimbabwe stated that 19.4% of kids were lost before 180 days, either "lost" kids or from predation (Ndlovu & Simela 1996). Undernutrition of the female may result in inadequate intake of colostrum, as has been shown in sheep (Mellor & Murray 1985), which aggravates the adverse effects of low birth weight.

Morand-Fehr(1987) has indicated that mortality of kids can be kept at low levels by careful management during and after parturition, by ensuring adequate colostrum intake, by avoiding stress and by improving feeding of dams and kids.

2.5.3 Kid Rearing Systems

Many systems of rearing kids can be used, but will depend upon management capabilities and facilities. The objective should be to raise the kids economically, without increasing the likelihood of diseases or mortality, or of reducing growth rates from the economic optimum. The system of allocation of milk or milk substitute, time of weaning, and form of supplementary feeding can be significant. For example, one study (Greenwood 1993) showed that kids grew best when reared using cow colostrum, pasteurized goat milk at 1.6 litres/day and an ad libitum ration (with 12.3 MJ Me/kg and 252.5gCP/kg DM) until weaning at seven weeks, and a liveweight of 12.8kg. However, this system may well not be the most economical option. Milk feeding may be for as short a time as 4 to 5 weeks, or as long as several months. Milk replacers for calves or lambs can also be used for kids, but replacement of milk proteins by soya or fish proteins may reduce kid performance. Natural rearing is recommended for meat producing herds, and also for milk producing herds where the price of milk substitutes is high or management is poor. Individual feeding of milk from a small pail is suitable. Ad libitum teat feeding may save labour, but will increase consumption. Restricted milk feeding will enhance intake of other feeds and reduce the adverse effects of weaning (Havrevoll *et al.* 1991).

Weaning can be a time of great stress, and blood glucose levels have been shown to fall from 1.2g/litre to 0.68g/litre, mainly as a result of the energy deficit (Bas & Morand-Fehr 1992). The intake of Metabolizable Energy reached pre-weaning levels only 6 to 8 weeks after weaning at 4 to 8 weeks of age (Bas *et al.* 1991).

Post-weaning feeding is greatly affected by age at weaning and intensity of production. Intensive systems where female kids are bred at seven months must ensure that they are fed well to grow to the required size in the time available. This often includes the use of ionophores and cereal grains (Hadjipanayiotou, Economides, Morand-Fehr, Landau & Havrevoll 1991). Many factors may affect growth rate (Ruvuna *et al.* 1991).

2.6 Nutrition

2.6.1 Nutrient Requirements

Nutrition will have a major effect on production of milk, and careful planning of a feeding programme is essential, as with dairy cows, to ensure adequate intake of roughage (Sauvant, Morand-Fehr & Giger-Riverdin 1991) and concentrates, and a sufficient supply of all nutrients required. One problem arises from the fact that less research has been done on the nutrient requirements of goats than in other species (NRC 1981). However, more recently, significant research has been carried out on nutrient requirements (Ademosun *et al.* 1992) and digestion physiology (Tisserand *et al.* 1991; Sauvant 1992). Specific reviews have summarized progress in defining nutrient requirements in terms of energy for growing goats (Sanz Sempelayo *et al.* 1991), and for adult goats (Sauvant & Morand-Fehr 1991); protein for growing goats (Hadjipanayiotou, Brun-Bellut & Lindberg 1991), and for adult goats (Brun-Bellut *et al.* 1991); mineral nutrition (Haenlein 1992; Kessler 1991a); vitamins (Kessler 1991b); and water requirements (Giger-Reverdin & Gihad 1991).

Goats are renowned as fussy eaters (Mackenzie 1980) and this may be an expression of their ability to select food of high nutrient content when grazing or browsing (Harrington 1982; Lu 1988).

2.6.2 Feeding Systems

The feeding system used for dairy goats will depend on the resources available (Devendra 1987b), ranging from extensive grazing systems (Cunningham 1982), to intensive grassland systems (Alexandre *et al.* 1996; Coop 1982), to very intensive systems (Orskov 1982). Forage trees like *Leucaena* can also be used for milk goats (Shenkoru *et al.* 1996) although probably more often used for meat goats (Mtenga & Shoo 1990). However, for good yields of milk from dairy goats, intensive systems are essential, to provide enough good quality roughages and concentrates (Demment & Longhurst 1987; Morand-Fehr & Sauvant 1980). Excessive walking will increase the nutrient requirements (NRC 1981), and milk production of goats may be limited by their ability to ingest sufficient nutrients (Morand-Fehr & Sauvant 1980). The most cost-effective feeds should be used (Stark 1987). Knowledge about the mineral requirements of goats is limited (Haenlein 1980). Underfeeding of nutrients may be detrimental, but overfeeding can also be undesirable, especially if there is an imbalance of nutrients or a lack of roughage in the total diet, leading to reproductive difficulties, acetonaemia or laminitis (Slater 1987). Intensive feeding systems for dairy goats have become more prevalent in recent years (Devendra 1992b). Where roughage is limited, more concentrates are fed, and the animals are often confined (Giger-Riverdin & Sauvant 1991; Hadjipanayiotou & Morand-Fehr 1991). In contrast, indigenous goats generally have to survive and reproduce in harsh environments with extremes of environment and an erratic and insufficient food supply (Meuret *et al.* 1991; Ramsay & Smit 1987). It is reasonable to assume that nutrition is therefore a major constraint on their productivity. If dairy goats or crossbred goats are to be introduced successfully in Southern Africa, appropriate and economic feeding systems will have to be devised. These should make use of sources of feed that are available, and should be sufficient to allow the goats to express their genetic potential. They should also be appropriate to the socio-economic circumstances of the people keeping the goats (Boyazoglu & Morand-Fehr 1987).

The assertion has been made that goats need to select food of high nutrient content as they do not digest low quality roughage to the same extent as cattle, because of their smaller size (Illius & Gordon 1991). However, this view can be challenged by evidence presented by Tisserand *et al.*(1991), who stated:

" with forages low in nitrogen content and high in cell walls and not properly supplemented, goats have a better digestive efficiency than other ruminants......ascribed to the longer mean retention time of digesta, higher concentration of cellulolytic bacteria...... and their higher efficiency for recycling urea ."

It is likely that a major constraint to many dairy goat owners will be the provision of sufficient quantities of good quality roughage (Masson *et al.* 1991; Schwartz & Carles 1987). In addition, for efficient rumen function, dairy goats because they are high-producing animals, like dairy cows , will need an adequate *proportion* of total dry matter intake in the form of roughage (Kawas *et al.* 1991). One way of overcoming both these constraints would be the use of a complete feed (Morand-Fehr *et al.* 1996; Reddy & Raghavan 1992), as is used for dairy cattle (Poole 1986). This also has advantages experimentally in eliminating variation due to differences in availability and selection of browse or grazing. Goats in Italy have been shown to produce milk efficiently in a zero-grazing system (Bufano *et al.* 1996). Growth promotants such as ionophores improve average daily gain and feed conversion of growing kids, but have not yet been thoroughly researched in adult goats (Schmidely & Hadjipanayiotou 1991).

3. GOAT MEAT PRODUCTION

Meat is usually the most important product of goat farming, and can also be a significant source of income for fibre and milk production enterprises (Smith,G.C., 1992). It is an important source of protein in many developing countries of the world (Casey 1992), especially in Asia (Saithanoo & Huq 1992); but is less important in the USA (Smith,G.C., 1992) and in Europe (Morand-Fehr *et al.* 1992). Marketing systems are either non-existent or poorly developed and managed (Wilson 1992; Mandebvu 1991). Meat hygiene is often poor (Gill & Joshi 1992). The efficiency of goat meat production will depend on the reproductive rate achieved, and on the survival and growth rates of the kids, as well as the availablity of suitable feed sources. Goat meat production development programmes have been attempted, but with varying success on natural vegetation (Carles & Schwartz 1992; Riviere 1991); and also with intensive feeding (Mandebvu & Prasad 1991). Research has been carried out on the effects on carcasses of breed (Hogg *et al.* 1992; Ruvuna, Taylor, Okeyo, Wanyoike & Ahuya 1992); of rearing and feeding systems (Morand-Fehr *et al.* 1991); and of castration (Anous & Shahin 1993). Aspects of carcass evaluation include conformation (Prasad & Kirton 1992); by-products (Kumar & Issani

1992); minerals (Wahid *et al.* 1992); fatty acids (Zygoyiannis *et al.* 1992); and palatability (Griffin *et al.* 1992).

4. DISEASES IN GOATS

4.1 Incidence of Diseases in Goats

Any disease which affects the well-being of a dairy goat will reduce milk production, either directly through the effects on the individual animals, or indirectly through a reduction in fertility of the herd and therefore in the initiation of new lactations. (The wide range of diseases that can affect goats is illustrated below). The severity of the impact on milk production will depend on the severity and nature of the disease. Thus some diseases will have little effect on herd productivity, such as isolated cases of carcinoma (Rajan *et al.* 1982); or a more general effect, such as with pneumonia (Hidalgo 1987); or a specific effect on fertility, such as with toxoplasma (Dubey 1987); or an effect both on goats and humans, such as with brucellosis (Kolar 1987). However, seldom have the effects of these diseases been quantified in terms of a reduction of milk production. At times the effects are severe, as for example when a herd of 700 goats had to be destroyed in California because of an outbreak of mycoplasmosis (Damassa *et al.* 1987); or when a herd of dairy goats in Zimbabwe had to be slaughtered because they were infected with CAEV (Harrison 1988).

A wide range of diseases can affect goats, and dairy goats in particular (Williams 1981), and herd health programmes should be instituted to prevent these (Bliss 1984; Guss 1983; Lebbie *et al.* 1996). However, goats kept extensively in communal grazing areas may be remarkably free of internal parasites and diseases (Obwolo 1991). Management and husbandry are particularly important during kid-rearing in intensive systems (Morand-Fehr 1985).

This section of the review will only briefly consider various diseases.

4.1.1 Infectious Diseases

Many infectious diseases have been documented, including: brucellosis (Kolar 1987; Singh, Singh, Singh, Vihan & Lalwani 1992); tuberculosis (Bernabe *et al.* 1991); Johne's disease (Singh, Vihan, Singh & Gupta 1992); enterotoxaemia (Ayers 1984b; Harbola & Ratan 1992); mycoplasma (Damassa & Brooks 1987; Jones 1989; Wesonga *et al.* 1993); caseous lymphadenitis (Dercksen *et al.* 1996; Gezon *et al.* 1991; Gonzalez & Tortora 1992; Olander & Brown 1987;); toxoplasmosis (Dubey 1987); pox (Mallick, Das, Goswami & Kishore

1992);foot-and-mouth disease (Shankar et al. 1992); pneumonia (Hidalgo 1987); mycosis (Chattopadhyay *et al.* 1992); coccidiosis (Smith 1984), and other diarrhoeal diseases (Ayers 1984a), such as colibacillosis (Singh, Vihan, Singh & Tiwari 1992; Vihan 1992a,b). Recent reviews have listed diseases affecting goats: bacterial (Sherman 1992); viral (Mallick, Shankar & Bansal 1992); protozoal and metazoal (Dubey 1992).

4.1.2 Coccidiosis

Coccidiosis is often considered to be a disease of intensification, affecting goat kids in particular (Vihan 1992b). However, it may also occur under more extensive conditions (Chhabra & Pandey 1992; Shrestha *et al.* 1992). One paper has reported cerebrocortical necrosis from treatment with amprolium (Lonkar & Prasad 1992). Monensin has been shown to reduce the effects of coccidiosis in lambs (Muwalla *et al.* 1994). Mortality rates of as high as 10% of does and 65% of kids have been reported (Sanchez *et al.* 1992). In another study, mortality from coccidiosis was 47% of a mortality rate of 9.9% of deaths from parasitic diseases (adults and kids), with most of the deaths occurring from three to six months of age (Sharma *et al.* 1992). It is possible that other infections may contribute to the effects ascribed to coccidiosis. In this regard, the identification of rotavirus in the MEDUNSA herd may be significant (DaCosta Mendes *et al.* 1994). Rotavirus has also been identified in goats in Spain (Munoz *et al.* 1994).

4.1.3 Caprine Arthritis Encephalitis (CAE)

Of particular note in recent years has been the extent and severity of Caprine Arthritis Encephalitis Virus (CAEV) (Adams *et al.* 1984). Although no reactors were reported from South Africa, one case was documented in Mozambique (Lopes Pereira *et al.* 1989), and in a research herd in Zimbabwe (Harrison 1988). Transmission appears to be through body fluids, primarily colostrum (East *et al.* 1993). This disease is very important in many countries of the world (Perrin & Polack 1992). Extension programmes have had some success in eradicating CAE (Greenwood 1992).

4.1.4 Tick-borne Diseases

Tick-borne diseases of importance in South Africa include anaplasmosis (Barry & Van Niekerk 1990) and heartwater (DuPlessis *et al.* 1983; Stewart 1987). These diseases are also important in other parts of Africa (Ilemobade 1982) and elsewhere (Matheron *et al.* 1987).

4.1.4.1 Heartwater

Heartwater is a disease caused by *Cowdria ruminantium*, transmitted by the tick *Amblyomma hebraeum* in South Africa (Walker & Olwage 1987). It affects cattle, sheep and goats in many parts of Southern Africa (van Winkelhoff & Uilenberg 1981) and elsewhere in the world (Matheron *et al.* 1987; Provost & Bezuidenhout 1987). Mortality has been reported to be high in Angora goats and Boer goats (Du Plessis *et al.* 1983; Du Plessis *et al.* 1986), but appears not to be well documented in other goat breeds in Southern Africa. Some degree of immunity can be induced by giving virulent heartwater blood and then blocking the disease with tetracycline when a temperature reaction is shown. However this procedure is risky, difficult to administer, and has a variable success rate (Poole,1962; Du Plessis *et al.* 1983). Immunity is difficult to assess serologically, and may be of limited duration (Stewart 1987).

The disease is characterized by a temperature reaction, and by clinical signs that can be associated with pain, fluid accumulation, and with damage to the nervous system (Prozesky 1987), leading to rapid death. The pathogenesis is not well understood (Du Plessis *et al.* 1987). Du Plessis (1985) proposed a "reaction index" to grade the degree of reaction between animals. However, the ideal would be to identify a marker or indicator that would be a good predictor of potential resistance, without the risk of mortality inherent in the present system of a direct challenge with the disease. Such a marker would make it possible to select resistant animals and study the mode of inheritance, thereby expediting the development of a resistant breed at greatly reduced costs in terms of animal suffering and mortality. There is some indication that resistance to heartwater may be linked to the presence of serum conglutinin in cattle (Du Plessis 1985; Du Plessis & Bezuidenhout 1979; Du Plessis & Malan 1987; Lachman 1967).

4.1.4.2 Anaplasmosis

Far less research has been carried out on anaplasmosis in goats in South Africa than on heartwater (Barry & Van Niekerk, 1990). This is presumably because it is perceived to be a less significant disease in goats than in cattle (FAO 1994).

4.1.6 Mastitis

Although mastitis is usually an infectious disease, its importance in dairy goats as in dairy cattle justifies listing it separately. It can affect milk production through sub-clinical as well as clinical infections (East *et al.* 1987; Guss 1984).

Losses are related, as with mastitis in dairy cows, to a reduction in milk production itself, as well as associated losses including the cost of treatment and the discarding of contaminated milk. However, such losses do not appear to have been quantified in dairy goat herds. Systems of controlling mastitis developed for dairy cows (Kingwill *et al.* 1979) should be applicable also to dairy goats. Diagnosis is in some ways different from mastitis in dairy cattle because of the unreliability of somatic cell counts (SCC) (Contreras *et al.* 1997; Lerondelle *et al.* 1992; Manser 1986; Park & Humphrey 1986).

Calfornia Mastitis Test (CMT), leucocyte counts, and lactose and chloride content were evaluated by Upadhyaya and Rao (1993) as measures of subclinical mastitis. The best correlation was between CMT and leucocyte count. Zeng and Escobar (1996) found no effect of breed of dairy goat or milking method on SCC. Over the whole lactation period, 51% of samples had more than one million cells/ml, but only traces of mastitis-related pathogens were found, which indicated that the high cell counts were not associated with mastitis infections. Wilson *et al.* (1995) also found that non-infected goats frequently had SCC greater than one million cells/ml, and suggested that an alternative measure of subclinical mastitis should be found for goats. Zeng (1996) has shown that the calibration of instruments used for measuring SCC had a significant effect on the results obtained, and this might be a reason for the apparently contradictory results reported. Other researchers have examined the different types of cells in goat milk. The proportion of polymorphonucleocytes increased during a lactation (Rota *et al.* 1993). Montaldo and Martinez-Lozano (1993) have shown a significant relation between udder conformation and mastitis incidence: globular udders and non-balloon-shaped teats were associated with lower levels of mastitis.

Vacuum level and pulsation rate used for dairy goats differ from those used for cows. Le Jaouen (1981) reported the requirement of levels of 38 to 44 kPa for goats compared to 50 kPa for cows; and 70 to 90 pulsations per minute for goats compared to 50 to 60 for cows. This means that a specialized milking machine that is effective is needed for goats, and Lu *et al. (*1991) have shown how effective milking is important for reducing somatic cell counts. Methods of treatment may also need to be different because of differences in udder function. For example, a report by Buswell *et al.* (1989) showed that the length of time that antibiotics may persist in milk can be longer than in cows. Selective dry period therapy might be all that is necessary if infected udder halves can be identified, as Fox *et al.* (1992) showed that there were few new infections during the dry period.

Causative organisms documented include *Mycoplasma* (Hasso *et al.* 1993); and Staphylococci (Maisi & Riipinen 1991). Bacilli, coliforms, micrococci, streptococci, corynebacteria and *Pseudomonas* have also been isolated from goat milk samples, but were not necessarily associated with clinical signs (Kalogridou-Vassiliadou 1991).

4.1.7 Internal Parasites

Internal parasites can have a significant effect on the productivity of goats, especially in intensive management systems (Anderson 1982; Cabaret *et al.* 1989; Schillhorn VanVeen 1982), but infestation is not necessarily always high (Chartier *et al.* 1992). Mortality has been reported to be as high as 20% from haemonchosis (Sharma *et al.* 1992). Coenurosis may be high in some areas in India (Gogoi *et al.* 1992). Some evidence of genetic resistance to internal parasites has been reported (Gill *et al.* 1991; Pomroy 1996); in some circumstances, different breeds of dairy goats have responded differently to treatment, as illustrated by the report of Richard & Cabaret (1992), documenting the variation in response to fenbendazole used to treat lungworm.

4.1.8 Nutritional and Metabolic Diseases

Nutritional diseases and metabolic disorders can be significant problems in goats (Dunn 1985; Lee & McIntosh 1982; Nelson 1984). These include ketosis resulting from high glucose demand and low availability, especially in late pregnancy. Parturient paresis may also occur, but is generally less of a problem than ketosis. These disorders can be prevented by correct feeding procedures (Sauvant, Chilliard & Morand-Fehr 1991). Abortion resulting from low blood glucose levels can be a particular problem in Angora goats (Wentzel 1982).

4.1.9 Other Diseases

Other diseases documented include those related to external parasites (Murray 1982); malignant melanoma (El-Hassan & Ramadan 1982);and ethmoid carcinoma (Rajan *et al.* 1982). Digital lesions and lameness can be significant (Mgasa & Arnbjerg 1993). Footrot can also be caused by *Bacteroides* and *Fusobacterium* (Duran *et al.* 1990).

4.2 Genetics and Disease Resistance

The significance of genetic effects on the ability of animals to resist various diseases is well documented (Nicholas 1987), but there appears to be little evidence of this recorded in goats.

Animal diseases are major factors limiting economic development in Africa (Jawara 1990), and the importance of developing breeds of animals that are resistant to diseases has been emphasised (Lefevre 1987a). This is especially so with diseases like trypanosomiasis (Griffin & Allonby 1979).

It is to be hoped that diseases like CAEV will never enter South Africa. However, there are many other diseases here that could be prevented if genetically resistant animals were available. For example, breed variations have been demonstrated in gastro-intestinal parasitism in Indian goats (Yadav & Sengar 1982); and resistance has been shown in the Kenya dual-purpose goat developed from crossbreeding (Ruvuna, Taylor, Davis, Mwandotto, Rurangirwa & McGuire 1992). Some Angora goats are genetically susceptible to abortions and should be culled (Wentzel 1982). Guadeloupe native goats have been shown to be resistant to heartwater (Matheron *et al.* 1987).

Ramsay & Smit (1987) reported on the adaptability of Indigenous goats in Southern Africa to survive in harsh environments when compared to Boergoats, particularly in an area where animals are liable to contract heartwater. The extent of any disease resistance should be established, and the effect of crossbreeding in relation to such disease resistance should be evaluated.

5. GOAT MILK PRODUCTION IN RURAL DEVELOPMENT

Small ruminant production systems in developing areas are usually associated with small-scale or subsistence production (Devendra 1996). The introduction of goats or the development of systems for improved production have to be carefully planned with the active co-operation of the people involved. Success has been achieved with milk goats in Tanzania (Mtenga 1992); but many difficulties have been encountered with a programme for meat production in Zimbabwe (Riviere 1991). Systems of production will vary depending on the people, the animals, environmental and economic factors.

5.1 The Farmers

Devendra and Coop (1980) outlined the characteristics typical of small-scale farmers and their livestock in many parts of the world:

* They are usually crop-oriented subsistence farmers with small land holdings (1 to 4 ha);
* Goats are kept because they involve little management, are a low-risk investment, and supplement income;
* The animals provide meat, milk, skins, fibre, manure, and by this diversification, provide insurance against crop failure;
* The animals make good use of crop by-products;
* Herd size is often very small (3 to 10 animals).

In addition to the products mentioned above, goats are kept as a source of supplementary income, provide some employment, have social, recreational and in some societies, religious functions (Devendra 1992a). Devendra and Coop(1980) identified the landless agricultural labourer as a further category of goat owner. Often the person who cares for the animals is a woman. This can result in problems of communication in countries where most of the extension agents are men, and there are social or religious barriers between them (Jiabi & Sinn 1992; Sinn & Wahyuni 1996). In addition, with the seemingly universal trend towards urbanization, there is a need to consider the potential of animal production in the peri-urban situation as well as in rural areas.

A major obstacle to progress in improving animal production among small-scale farmers is illiteracy and the low level of education. However, a study of the target population and their perceived needs will assist extension workers in developing appropriate programmes. Literacy is an asset but is not essential if the people are well motivated. The methods of agricultural extension are well known, and techniques can be used that are appropriate to particular circumstances. In essence, agricultural extension is a form of adult education, and can achieve results according to well-planned strategies, but the rate of change is often slow for whole communities, even though it may be rapid for specific individuals (Bembridge 1991).

5.2 The Animals

The existence of large scale commercial flocks of sheep has resulted in most of the research on small ruminants being applied to sheep. However, in the context of Africa, greater emphasis needs to be placed on goats (Donkin 1988), although sheep also have a significant contribution to make (Raats 1988). Devendra and Coop (1980) listed characteristics of goats that would influence their suitability for different environments and systems of production. Goats are resistant to dehydration, prefer a low rainfall environment and are usually found in the tropics; they have a preference for a variety of feeds, especially browse, and are very selective; they are usually kept for meat production, although milk production is a common secondary function (especially in temperate regions); and fibre is important for mohair and pashmina (cashmere) production. Goats have a greater susceptibility to exposure and stress than sheep, in part because they have hair coats, and because fat distribution is visceral rather than subcutaneous. They may be sensitive to pneumonia, gastroenteritis, parasites, and contagious ecthyma, but are said to be resistant to tsetse flies. In many developing areas the existing animals are probably well adapted to survival within the prevailing environment and social systems. There has been little attempt to breed animals with a specific purpose in mind, and those that were unable to adapt have died out. In these circumstances, low productivity, such as the absence of multiple births, may be beneficial. The prospects of genetic improvement by selection are negligible because of the small herd numbers, and the lack of control and records (Ricordeau *et al.* 1992). Many attempts have been made to crossbreed in order to introduce supposedly desirable characteristics to local breeds. (See Section 2.1.3). Breeding between crossbred animals will result in the development of a new breed, but large populations will be necessary, and selection will have to be sustained over a long period (Rae 1980). Unless the environment is improved in some way, by providing better control, nutrition and health care, there may be little benefit in breed improvement.

5.3 The Environment

The environment in its broadest sense consists firstly of natural constraints or advantages such as the climate and soils, vegetation and diseases; and secondly, the influence of the people, in how they organize their lives and those of their animals. The first category is one which can hardly be changed; but the second offers great hope, because the animals often have great potential for improved productivity following small changes in how things are done.

5.3.1 Forage Supply

Poor nutrition is often the greatest constraint to improved productivity, shown as a complete or seasonal shortage of energy, protein, macro-elements (such as phosphorus) or micro-elements (such as selenium). Shortages of protein or minerals can be remedied by the provision of a suitable supplement, if not too expensive; but a shortage of roughage is less easily solved.The smallholder farmer who keeps goats might well consider using trees and bushes, often referred to as "agroforestry". *Leucaena leucocephala* is one species that has been used in many parts of the world (Girdhar *et al.* 1991), but may have certain problems because of the toxin mimosine (Fernandez *et al.* 1992). This problem can be resolved by transferring to susceptible animals rumen microbes (*Synergistes jonesii*) which are capable of degrading mimosine to innocuous constituents (Jones 1981; Hammond 1995). A method of identifying and establishing suitable plants in Central America has been described by Benavides (1992). Some indications of the potential of indigenous fodder crops in Kenya have been given by Kihia (1992). In Africa and elsewhere in the world (Sheehy 1988; Singh 1992), major problems of environmental degradation have occurred because of the system of communal land tenure for grazing with the paradox of individual ownership of animals (Bembridge 1987); and also because of conflicting goals within communities (Russo & Spencer 1988). However it is possible to develop methods of livestock management including feeding, within mixed farming systems (Hardesty 1988).

Improved systems of production from goats will require an improvement in the supply of roughage. This process will involve some form of intensification as natural grazing becomes scarce (Smith,O.B., 1992). In very intensive systems such as those that apply in a peri-urban situation it is possible to use complete feeds, provided that they are cost-effective (Donkin 1991).

5.3.2 Fertility Management and Breeding

Management must involve some control. Problems with systems of communal grazing include the uncontrolled breeding that occurs. I am not aware of any studies that have demonstrated the extent of inbreeding in these situations, and it would be very difficult to measure. However, it is likely to be high where herds or flocks are small, the animals reach puberty at an early age, and many males are left uncastrated. A change in the system of management to allow the owner to exert control would require separation of the ram or billy goat from the female animals. This would imply confinement, and with that the provision of feed and water. A similar change in management would have to be applied by neighbours, and some social structure would be needed to ensure compliance. In situations where communal grazing is the traditional system, this would be a radical change. When male animals are separated, management procedures such as comparison between animals, culling, selection, breed improvement, the choice of the optimal breeding season, and uniform marketing become possible. The real difficulty may be the social problem of developing trust and understanding so that such mutual co-operation can take place.

5.3.3 Disease Control

Management systems for the control of diseases commonly encountered must be developed which are easily applied in the particular circumstances by the people concerned. These would normally involve vaccinations and the control of internal and external parasites. Management techniques such as the development of appropriate housing that is elevated and has slatted floors for the humid tropics (Appleman 1984) or simple shelters and energy supplementation for protection from bad weather may be needed (van der Westhuysen *et al.* 1988). The introduction or development of breeds with resistance to specific diseases may be required, as in the case of heartwater (Donkin *et al.* 1992).

5.3.4 Markets

While the primary aim may be to ensure self sufficiency in a subsistence economy, even the basic household economy has a need for some cash income (Low 1986). Local selling of animal products such as milk may generate some income, but it will be the rare entrepreneur that will develop a commercial enterprise. A marketing opportunity must be available, and sufficient resources at hand, such as feed supplies for the animals (Donkin 1991).

Government supported development of marketing opportunities may have a substantial effect in improving income for small-scale farmers, and also in developing secondary industries, as exemplified in the great progress made in the leather industry in India in the last few years (Rao & Rao 1992).

5.3.5 Support Services

Development can be stimulated by active programmes of animal and human health care, literacy, agricultural extension, marketing systems, financial services, communications, roads and other infrastructure. Priorities should be established according to local and national needs, but should always involve the willing participation of the communities themselves. A developed agricultural sector can be important in supplying some of the inputs for developing areas, such as improved breeding stock, technical expertise, and the vision and belief that improvements are not only necessary, but are also possible.

5.4 Economic Factors

The economics of development programmes must be evaluated within the context of the recipient community. A programme will not be adopted if it is not perceived to be of benefit and to be self-sustaining. The economy of the household, which involves family labour and time allocation as well as money, must be considered (Low 1986). Often a small input can develop to be a significant influence for improved prosperity and quality of life, as has been achieved in some projects of Heifer Project International (Jiabi & Sinn 1992). The importance of marketing in developing an enterprise from subsistence to a commercial venture has already been noted.

5.5 Complete Systems

Complete systems can be developed that will take account of all the factors required for success in a particular situation. Such systems will have to be formulated by development agencies, as the resources are not usually available to the small-scale farmer. Innovation is a risky business, and the chance of failure in introducing new techniques or systems is high. In the same way, the extension officer may risk losing credibility if the project is a failure. Therefore there is no substitute for careful research, imaginative "hands-on" practical experience, involvement of others in a multi-disciplinary approach, and above all, involvement of the people concerned on a sustained basis. Traditional "top-down" planning and implementation of development has seldom worked. Effective development is ultimately a development of the people, not only of the animals. Development should be planned to be as simple as possible, although complexity may follow. This approach is probably best seen in the programmes that use Farm Systems Research and Extension (FSR-E), such as the on-farm evaluation carried out in Kenya by Semenye *et al.*(1989). Potential areas for the promotion of development of small-scale farming must involve intensification, as the population pressures increase and resources become more limiting. This has already happened in countries like India where many goats do not graze or browse, but are confined and have their feed brought to them. A comprehensive and multi-disciplinary approach in development has been shown in the Small Ruminant Collaborative Research Support Program (SR-CRSP) in Kenya, Peru, Brazil, Indonesia, and Morocco (Raun 1989). Aspects of genotypes (Bradford *et al.* 1989); feeding (Johnson & Djajanegara 1989); animal health (Alexander *et al.* 1989); sociology (Nolan *et al.* 1989); and the on-farm evaluation of dual-purpose goat production systems in Kenya (Semenye *et al.* 1989) have been well documented.