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ALTERNATIVES FOR THE UTILIZATION OF TROPICAL SHEEP AND GOAT GENETIC RESOURCES FOR THE TROPICS[1]

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ABSTRACT

The genetic diversity of sheep and goats found in tropical areas of Latin America provides an opportunity for geneticists to mold desirable combinations of genes resulting in greater productivity. Successful manipulation of these animals will depend upon the animal breeder being cognizant of the production system the animals are to perform in and the wide range of tools that the animal breeder can use. it is suggested that a holistic approach in evaluating genetic resources be applied. To facilitate such an approach systems analysis and computer simulation should be incorporated into the design phase of animal breeding experiments.

INTRODUCTION

As we approach the year 2000 there is a growing consensus that sheep and goats are important to agricultural systems. Animal geneticists will play a key role in assuring that these species realize their potential performance. This change of perception has more to do with a social attitude, not a biological alteration. The realization of the economic importance of small ruminants has also contributed to this change. Due to long periods of minimal research activities the potential available for biological manipulation is relatively high. An example of the level of funding that small ruminant research has received was given by Jarvis (1986). He stated that in Latin America only 5% of the World Bank's livestock assistance was allocated for small ruminant development projects.

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Sheep and goat production in Latin America are given by country in Table I. It has been estimated that 2% of the meat consumed in Latin America is lamb or mutton, while less than 1% is goat. Consumption of sheep is about 5% in Argentina, Bolivia, Chile, Ecuador, El Salvador, Peru and Uruguay, while goat consumption is above 5% in Bolivia and Haiti (Jarvis, 1986). However, these figures probably do not incorporate on--farm consumption of sheep and goat products, which can be extremely important in specific regions of a country. Table II demonstrates how Latin American trade for sheep and goat products has increased from 1971 to 1980. Although previous levels of economic and research activity have been low it does appear that this trend is changing. Devendra (1987) cites projections that demand for goat milk and meat are increasing 2.8% per year. Furthermore, demand for sheep and goat products is increasing at a faster rate than for other food commodities. In addition it appears that more development and research projects have been designed to investigate small ruminant production in the tropics (Winrock International, 1983).

Table I - Production of sheep and goat products in Latin America, 1980 (thousands of metric tons).

Country	Mutton and Lamb	Goat	Wool
Latin America	284	95	514
Argentina	116	6	254
Bolivia	20	6	13
Brazil	29	23	50
Chile	16	5	31
Colombia	9	3	2
Costa Rica	_	_	_
Dominican Republic	_	1	_
Ecuador	8	1	5
El Salvador	_	_	_
Guatemala	3	_	_
Honduras	_	_	_
Mexico	16	20	13
Nicaragua	_	_	_
Panama	_	_	_
Peru	21	10	19
Uruguay	37	_	121
Venezuela	3	10	_

From Jarvis, 1986.

Table II - Trade in sheep and goat for Latin America, 1971-1980 (million of current U.S. Dollars).

	Expoorts		Imports		Net Exports or Imports		Share of World Exports of Products, 1980 (Percent)	Share of Latin America Agricultural Exports, 1980 (Perce nt)
Product	1971	1980	1971	1980	1971	1980		
Mutton, Lamb Goat	16	51	9	23	7	28	3.6	0.2

From Jarvis, 1986

A major driving variable for the change of perception regarding small ruminants is the recognition of the role they play in smallholder production systems as well as larger commercial operations. For example, Baker and de Souza Neto (1989) found that there is good potential for dual purpose goats in Northeast Brazil, due to goats being inexpensive to buy and maintain and their ability to withstand drought. However, they state that for dual purpose goats to be viable milk production will have to be substantially increased. This will require not only genetic improvement but also a concerted effort to reduce other biological and social restrictions of the production system.

In addition to alterations in the perception of small ruminants there is a changing philosophy on altering genetic resources. Principally the research community is more aware that maximum utilization of ruminant gene pools is dependent upon production system the animals are to be produced in. That is, the genome interacts with the physical, nutritional, managerial and social components of the environment. This approach differs from the earlier concept that livestock productivity can be improved by importing livestock from temperate countries.

The way in which sheep and goats are optimally interfaced with different ecological areas is dependent upon the physical resources which are available for utilization and the objectives of the producer. It must be recognized that these physical resources can be some of the most limiting factors to production. As small ruminant production shifts from ecozone to ecozone, potentials and limtiations will change. For example, in arid or semi-arid environments small ruminants tend to be extensively managed in large herds. opportunities for genetic improvement in these types of systems are feasible when hierarchical breeding structures are implemented as has been the case in Australia, the United States and Uruguay (Ferguson, 1976; Cardeallino and Ponzoni, 1986). As environmental conditions become less constraining, optins for different tupes of sheep and goat production systems increase. For example, the opportunities to increase reproductive performance improve when sheep are placed on cultivated pastures. In such a situation not only is nutrition improved but also animal identification, which facilitates record keeping systems, becomes practical. However, a new set of problems could arise, such as, increased infestation by internal parasites. A third scenario in which sheep and goats are raised in the tropics are smallholder production systems. In these situations sheep and goats are raised by producers which have more l;imited economic resources. Sheep and goats can be produced in conjunction with cropping systems, by utilization of crop aftermaths and fence row grazing, or in an extensive grazing system on communal lands. These types of production scenarios pose special problems for animal breeders, and it is critical that all principal system components be fully evaluated before breeding programs are set in place.

TRADITIONAL ANIMAL BREEDING APPROACHES

Before animal breeders and geneticists can adequately address potential selection criteria, mating systems or crossbreeding plans, the issues of quantifying the genetic resource must be resolved. These have usually been addressed by evaluating a breed or breeds in one or two environments with limtied management alternatives being simultaneously tested.

Major characteristics which should be included in breed resource evaluation or characterization have been termed primary and ancillary characters by Cartwright (1982). Similar efforts have been put forth by Fitzhugh and Bradford (1983). Primary characters are those which have direct influence on the productivity of a breed resource, while ancillary characters affect production indirectly by limiting or enhancing an animal's ability to reach its genetic potential for the primary characters, or by affecting the quality of the product (Cartwright and Fitzhugh, 1988). A list of primary and ancillary characters is presented in Table III. It is noted that various measures of reproduction are not included as primary characters due to their interactive nature with the characters listed as primary characters. Determination of a breed's primary characters is essential in determining how well the genotype will fit into a production setting. The primary characters are mainly responsible for determining the level of animal performance and therefore the nutrients necessary to support that level of performance. It should also be noted that the primary characters interact with one another.

At this point in time a number of works have been published about the performance of sheep and goats in the tropics (Fitzhugh and Bradford, 1983; Figueiredo, 1986; Shelton *et al.*, 1986; Rajab, 1987; Burfening *et al.*, 1989). The data generated in these studies usually provide information on body weight measurements, growth, reproduction, mortality, milk production and fiber production. As a result of these and additional studies there is a growing awareness of the potential usefulness of indigenous breed resources, particularly for adaptation and disease resistant characteristics. A clear example of this was reported by Botswana researchers (Apru, 1984), where Tswana and Boer goats were compared. The Boer goat had faster growth rates and a larger mature size, however, the Tswana had higher reproductive rates and lower mortality rates resulting in more kilograms of kid produced per doe.

Table III - Primary and ancillary characters which influence the productivity of a genotype.

Primary characters	Ancillary characters	
	Anatomical Soundness	Physiological Soundness
	Reproduction	Adaptability
Mature size	Sex orrgans	Climate
Maturing rate	Udder and Teats	Altitude
Lactation	Birthing Ability	Nutrition
Ovulation rate	Muscle, bone and fat	Mobility/Confinement
Fiber growth	Structure	Diseases/Parasites
(sheep and goats)	Deposition Pattern	Reproduction
	Ratio	Seasonality of Estrus
	Feet and Legs	Hormonal Balances
	Horned/Polled	Birthing Ability
	Genetic Defects	Temperament
	Hair color	Other*
	Hide Pigmentation	
	Fiber Characteristics	
	Other*	

*This list is not complete because of insufficient knowledge.
From Cartwright and Fitzhugh (1988).

A Brazilian example of breed evaluation was reported by Rajab (1987) who analyzed data collected in Northeastern Brazil. Using this data set he was able to quantify base levels of production for the Brazilian Somali, Morada Nova and the Santa Ines. The characters evaluated were growth traits, reproduction and mortality. Breed differences were significantly important for all growth characters studied. In general the Brazilian Somali were smaller than the Santa Ines with the Morada Nova being intermediate (Table IV). These differences in size are primarily a function of mature body size. Rajab's (1987) results also indicated that the Morada Nova breed was the most prolific of those tested (Table V). Although the above information is useful and provides insight as to how these different breeds perfomred at one station, it does not provide information as how these breeds might respond and compare with each other when management, nutrition or environmental conditions change. This points out a critical deficiency in traditional animal breeding practices. That is: limited time, physical resources and genetic resources to evaluate diverse combinations of genotype, management and nutritional options. A second deficiency in evaluating different breeds for utilization in the tropics is not having appropriate measures of total flock productivity. Many types of production indices have been formulated to evaluate individual animal performance (Wilson and Light, 1986). However these measures tend to be specific to one part of a production system, e.g. using weaning weight in the numerator of the efficiency equation. Therefore they are not true measures of efficiency. Only when all the inputs and outputs of a system are accounted for can efficiency be measured.

Table IV - Least-squares means and standard errors for lambs birth weight (BWT), weaning weight (WWT), eight-month weight (WT8M) ten-month weight (WT10) and yearling weight (YWT).

Breed	BWT, Kg		WWT, Kg		WT8M, Kg		WT10M. Kg		YWT, Kg	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Somali	2.0	.1	13.8	.5	13.2	.5	17.0	.8	16.7	.8
Santa Ines	2.8	.1	19.4	.6	18.8	.6	25.2	.9	24.3	.9
Morada Nova	2.4	.1	15.9	.6	15.3	.6	20.5	.9	19.0	1.1

From Rajab (1987)

Table V - Least-squares means and standard errors for ewe prolificacy rate (PR) and weaning rate (WR).

Breed	PR		WR	
	Mean	SE	Mean	SE
Somali	1.39	.05	1.45	.02
Santa Ines	1.31	.05	1.50	.02
Morada Nova	1.82	.05	1.46	.02

From Rajab (1987).

Cartwright and Fitzhugh (1988) have pointed out that much more emphasis should be placed on how the population or flock of animals perform, not just the individuals. Total flock productivity can only be evaluated by measuring the inputs and outputs of the production system. Measuring flock or herd production efficiency is the only way in which the genetic component can be evaluated along with the interactions between genetic and non-genetic factors. Hohenboken (1986) has suggested that a more complete evaluation of breed resources is accomplished by comparing economic efficiencies of different breeds or strains on a flock basis. This should be performed on a lifetime basis or by comparing flocks of the same age structure for each genetic group on an annual basis. A possible hindrance in the proposed evaluation is the assumption that the flocks compared are in a steady state and that environmental conditions are constant. Therefore the robustness of the breeds tested is not known.

Moving from an evaluation of individual performance to flock performance requires that additional techniques be utilized. A technology which can help overcome the obstacles of time, flock structure and total flock productivity is that of computer simulation, which will be discussed in the next section.

SYSTEMS ANALYSIS AND COMPUTER SIMULATION

Using computer simulation models to address problems in determining breed utilization, breeding objectives and selection criteria provides animal breeders with the ability to address these issues in a holistic manner. To some, the use of computer simulation in this way may be rather new. But a review of the literature shows that this approach has been used at least since 1977 (Sanders, 1977). Over this time interval, simulation models have improved in accuracy and precision, which is essential if they are to provide insight on improving production systems. With such models, alterations in primary characters can be evaluated in differing managerial and environmental conditions. An a priori evaluation of breeding strategy allows for the conservation of time, labor and physical resources in addition to deeper insight into the relationships previously mentioned. Several studies document the use of computer simulation in this way (Ordonez *et al.*, 1979; Blackburn and Cartwright, 1987b; Figueiredo *et al.*, 1989).

The primary advantages of systems analysis and computer simulation is the ability to extend data collected on breed resources and test the impact of detrimental environmental conditions. For example, once data have been collected on a breed or breeds the question often remaining is how these genotypes will respond to varying levels of nutrition or management practices. With computer models it is possible to address these types of questions. Furthermore, simulation can evaluate how new genotypes will respond to extreme environmental hardship, such as occurs with drought.

By examining the reasons traditional animal breeding programs have been less than successful, the role that computer simulation can play becomes evident. Cartwright and Blackburn (1989) have discussed some of the reasons why animal breeding projects are not a successful as anticipated, these are:

1. Failure of financial support for a sufficiently long term;
2. Change of design and objectives before completion of project;
3. Great diversity of the socioeconomic and physical environments;
4. Failure to analyze and utilize data;
5. Lack of infrastructure to support improvement programs as designed;
6. Projects being based on disciplinary rather than total production systems designs, and
7. Socioeconomic interactions with livestock production systems which are based on mixed farming, not being understood or appreciated.

Characteristics of successful breeding projects include:

1. Sufficient numbers of trained personnel to form a critical mass of scien tists who are interested in the local small ruminant production system;
2. Incorporation of indigenous livestock into the program, and
3. Recognition of specific and general adaptability features of each environ ment.

If successful small ruminant breeding programs are to be established and carried to the next phase, implementation by producers, the previously mentioned factors will have to be considered as well as methods required to disseminate the technology or altered genetic material to them. In many instances the market place will help this transfer, if the technology or genetic material is markedly superior. However, for certain production systems, namely that of the smallholder, steps will have to be taken to facilitate the transfer of genetic material or improved breeding practices.

The transfer to smallholders may require government intervention to establish programs that would develop nucleus herds in which selection and breed development could be practiced. Larger scale producers will most probably be able to access information generated by genetic research and implement it in their production setting with less assistance than smallholders.

For genetic research to have maximum impact on targeted clientele when the complexity of the system we are dealing with is appreciated, it must be realized that: genetic and environmental inputs are both important and interdependent, genetic x environmental interactions may be large, genetic and environmental effects and objective functions may vary across time and location, and an integrated, multidisciplinary approach must be taken (Cartwright and Blackburn, 1989). using computer simulation and systems analysis facilitates the integration of components of the system and as serves as a conduit for multidisciplinary interaction.

Three examples of how systems analysis and computer simulation have been employed to assist in animal breeding programs will be presented. These examples include altering primary characters, evaluating the response of different genotypes to drought conditions, use of supplementation to improve the performance of different breeds and the use of computer simulation to determine breeding objectives and selection goals.

The first example uses the Texas A&M Sheep Simulation Model and concerns sheep production in Northern Kenya (Blackburn and Cartwright, 1987a,b). Primary characters of mature size and milk production were evaluated in normal forage production years, a drought year and in two years of drought recovery. Using computer simulation it was demonstrated that sheep of a small mature size and high milk production were not well suited to the tested environment; these genotypes did not recover from the drought (Figure 1). Genotypes with an intermediate or large mature size in conjunction with an intermediate or high level of milk production were better suited to this environment. The existing genotype was one of an intermediate mature size and level of milk production. Therefore, it was concluded that if genotype was to be altered in this environment sheep should be selected for a larger mature size and concurrently selected for higher quantities of milk production. it was also shown that if one of these characters was selected for but not the other the new genotype would not be as successful as the existing population.

In Northeastern Brazil the year is divided between a wet and dry season. During the dry season nutrient intake is limiting. Therefore, it was of interest to evaluate how different breeds of hair sheep would respond to higher levels of nutrition. The sheep model (Blackburn and Cartwright, 1987a) was parametrized to simulate all three breeds and then to alter their nutritional environment by supplementing lactating ewes with either 200 g/d or 400 g/d of napier grass. The simulations provided quantitative information on how the different breeds responded to alterations in their nutrition. Table VI demonstrates how the different breeds responded to two levels of supplementation. The greatest responses were associated with breeds of large mature size. It is interesting to note that although the Santa Ines had the greatest response to nutrition it did not surpass the Morada Nova. This implies that the Santa Ines is still nutritionally deficient despite the management intervention. Biological efficiency is reported in Table VII. No increase in efficiency for Brazilian Somali and Morada Nova were found in the simulation. This implies that although productivity levels may have been increased, efficiency of the systems was not enhanced. Biological efficiency did increase for Santa Ines indicating that not only was performance increased but also the system became more efficient as a result of the supplementation policies tested. This result gives us insight as to how these breeds need to be used. That is to get the greatest level of return from the Santa Ines in the Northeastern Brazilian en-

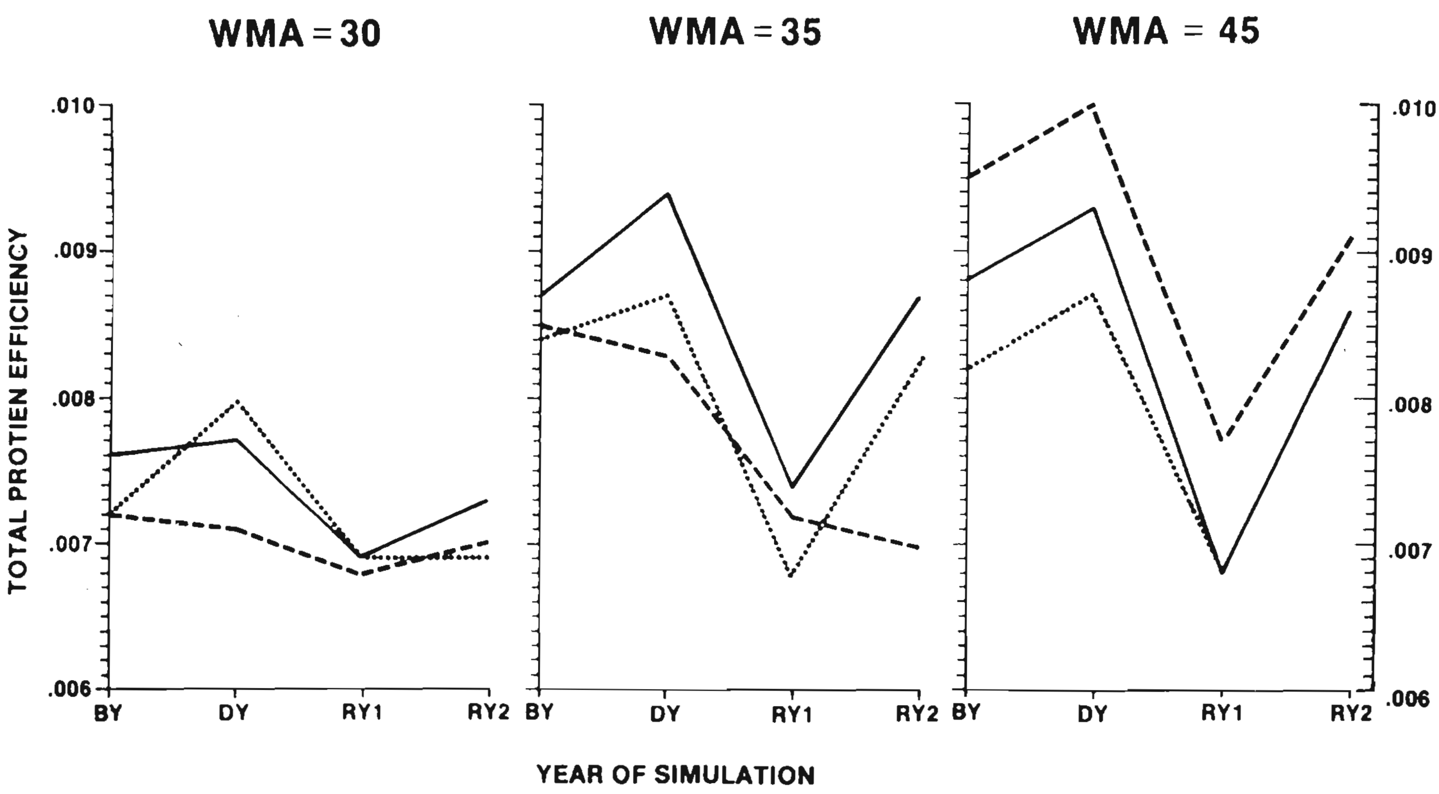

Figure 1 - Protein efficiency within a potential mature size (WMA) and potential peak milk production (GMLKL; 90 = dotted line, 1.30 = solid line and 1.75 = dashed line). From Blackburn and Cartwright (1987b).

vironment the sheep should be supplemented. The other two breeds will produce more with supplementation but supplementation is not as critical to their levels of performance.

Table VI - Average simulation results from two levels (I and II) of supplementation of Brazilian Somali (BS), Morada Nova (MN) and Santa Ines (SI).

Character	BS		MN		SI	
	I	II	I	II	I	II
Lamb mortality rate, %	8	9	16	11	8	7
Lamb weaning weight, Kg	15.2	16.6	16.0	16.3	19.9	20.6
Prolificacy rate	126	140	147	155	106	123
Ewe lambing, Kg	33	34	35	38	45	50

Level I is S 200 G/D of napier grass supplementation.
Level II is 400 G/D of napier grass supplementation.
Prolificacy rate = number of lambs born/100 ewe lambing.

Table VII - Simulated measures of efficiency from two levels (I and II) of supplementation of Brazilian Somali (BS), Morada Nova (MN) and Santa Ines (SI) flocks.

Character ratio	BS		MN		SI	
	I	II	I	II	I	II
Lamb sold/100 ewes	82	97	84	99	53	81
Lamb wt. sold/ewe, Kg	26.2	32.6	26.8	33.7	19.2	30.6
Lamb wt. sold/100 kg dm, Kg	3.6	3.5	3.7	4.3	2.9	3.5
Lamb + ewe wt. sold/100 kg dm, Kg	4.1	4.1	4.3	4.1	3.6	4.3

Level I is 200 G/D of napier grass supplementation.
Level II is 400 G/D of napier grass supplementation.

The development of breeding objectives has not received the attention that other topics such as estimation of breeding value have. This is due in part to the concept previously held that if a character is linearly increased, productivity will correspondingly improve. James (1986) has stated that development of breeding objectives should be based upon a combination of economically important traits we would like to improve, regardless of their heritability.

Table VIII - Four year average and coefficient of variability (%) for biological efficiency in different simulated genotypes.

Genotype	Efficiency	
	AVG.	CV
LLL	47	1.3
LLM	51	1.5
LLH	54	1.8
LML	47	3.2
LMM	52	2.4
LMH	55	2.9
LHL	48	4.9
LHM	53	2.0
LHH	54	1.2
MLL	48	3.0
MLM	52	1.6
MLH	55	2.3
MML	48	2.3
MMM	51	3.9
MMH	56	4.7
MHL	48	4.0
MHM	53	3.2
MHH	54	8.3
HLL	41	7.9
HLM	45	4.4
HLH	45	5.4
HML	44	4.3
HMM	45	5.3
HMH	47	12.0
HHL	43	6.1
HHM	45	7.2
HHH	50	6.1

From Figueiredo *et al.* (1989).

An a priori attempt at determining breeding objectives and the direction a population should be selected has been reported by Figueiredo *et al.* (1989). In this study simulation was used to determine how Morada Nova sheep in Northeast Brazil would respond if their genotype for any or all of three primary characters was altered. The primary characters tested were genetic potential for mature size, peak daily milk production and ovulation rate. Each of these characters was raised or lowered by 25% of the base genotype, which was considered to be 40 kg for mature size, 1.5 kg of milk at peak day of lactation and an ovulation rate of 2.2 ova per ovulation. Based on simulated production characteristics of the flocks, it was concluded that there were several genetic combinations different from the base genotype which could increase the productivity of the Morada Nova. A principal indicator used in ranking genotypes was biological efficiency (Table VIII), with output expressed as total weight of offtake and input expressed as dry matter consumption of the flock. Results showed that annual efficiency of meat production increased when genetic potential for ovulation rate was raised from the base, but decreased with increased genetic potential for mature size. The most efficient genotype was (in order of potential for mature size, milk production and ovulation rate) 40/1.50/2.75, it was followed closely by 40/1.125/2.75 and 30/1.5/2.75. The movement of potential milk production around the base level indicates that efficiency of this production system may not be too sensitive to changes in milk production at the tested levels. However, this is not to say that milk is totally impervious in its impact on the productivity of Morada Nova sheep.

These examples provide insight as to how simulation and traditional animal breeding approaches can and should be used in conjunction. Such an approach serves to extend physical world data, therefore making it more cost effective to collect. Additionally this approach allows researchers to make more specific recommendations for each geographic/socioeconomic setting concerning the utilization of sheep and goat resources.

CONCLUSIONS

The previous discussion has centered around a methodology to evaluate and improve breeds of sheep and goats. Before any improvement can be made the basic productivity of the indigenous breeds must be evaluated under several management alternatives in order to allow researchers to evaluate the potential genetic and environmental interactions which may exist. This will also provide a basis to determine the robustness of different breeds as well as their short-comings. To adequately address how breeds may respond and to determine their potential utility, a holistic approach to evaluating them must be followed. That is, production systems as a whole must be identified first. Then the contribution of small ruminants to the production system can be more completely evaluated. Consideration of not only the biological aspects of the sheep and goat is necessary but the social, economic and agronomic aspects of the production system must also be considered. This is not to imply that animal breeding experiments should not be initiated or continued. On the contrary, they are needed to confirm recommended simulation results.

Such an approach makes the application of animal breeding principals more complex. Traditionally, animal breeders and quantitative geneticists have been primarily concerned with selection for a few traits; assuming that moving the population to a new mean, which usually meant increasing some measure of animal production, would result in an increase in net animal performance. Unfortunately this has not always been the case where environmental conditions are harsh. As has been pointed out in this paper system analysis is a methodology which can assist geneticists in evaluating key criteria to select for, the appropriate combinations of chracters to alter in a population and how far to move the mean of the population in the selection process. Having this kind of capability to address long term questions and issues in a reduced time frame has benefits not only to geneticists but also administrators and society.

At this point in time many of the breeds of sheep and goats in the tropics have had little selection pressure placed upon their populations; the result is that their populations have lower levels of performance than what might be deemed desirable. However, that is not to say that these breeds do not have the potential for improvement. For example, the Dorper and Blackhead Persian sheep have been improved and selected for and are considered to be productive sheep. For many situations the South African Boer goat has desirable levels of productivity. While in Kenya the development of a new composite breed of goats which is designed for milk and meat production in smallholder production systems has potential for improving smallholder economies (Cartwright, 1984). The point is that indigenous sheep and goats may have the potential to serve in a greater capacity, either as purebred populations or in a crossbreeding scheme, when appropriate breeding programs are designed and carried out for sufficient periods of time.

The recent advancements in systems analysis, computing power, statistical analysis and molecular genetics will make genetic improvement and utilization of sheep and goats more feasible. In addition, by using all methodologies in concert, the speed and accuracy with which new levels of productivity can be reached should be enhanced, while counterproductive intervention can be predicted and avoided.

RESUMO

A diversidade genética, dos carneiros e cabras, encontrada nas áreas tropicais da América Latina dá aos geneticistas uma oportunidade de moldar combinações desejáveis de genes resultando em uma maior produtividade. A manipulação bem sucedida desses animais dependerá do criador estar ciente do sistema de produção que seria usado e da grande variedade de ferramentas que podem ser usadas. Sugere-se que seja aplicado um sistema que incorpore todos os fatos para avaliar os recursos genéticos.

Para facilitar o uso de tal sistema, análises e simulações em computadores deveriam ser incorporadas na fase de montagem dos experimentos de cruzamento dos animais.

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