GENETICS FOR THE IMPROVEMENT OF GOAT MEAT PRODUCTION

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SUMMARY

Production of meat was the earliest objective of domestication of goats. Today, more than 90% of the goat population is in developing countries where goat meat and meat products are considered as one of the most important sources of income. In these countries, the consensus that crossbreeding increases productivity under local conditions and requirements has led to the importation of various exotic breeds with larger frames, heavier mature weight and greater milk production. These breeds have been used for crossing with highly fertile and smaller indigenous goats with lower requirements and performance. This crossing has often led to the loss of important qualities such as adaptability and disease resistance resulting in the poor performance of the crossbreds and composite populations. Most of the past goat research involves their use as experimental animals. Currently, in meat goats, more studies are being carried out on breed evaluation, crossbreeding, synthesis of new breeds, estimation of genetic parameters and selection for economically important morphological and production characteristics. Nevertheless, precise estimates from large data sets and selection studies are still lacking. The major advances made in animal breeding have come from the application of quantitative methodologies to improve livestock and poultry. Meat goats have not been exposed to scientific advances made in genetics, nutrition and husbandry to the same extent as other livestock species. Application of this knowledge together with the advances being made in molecular methodologies could accelerate genetic response to selection and lead to the development of more effective breeding programs.

Keywords: Goat; meat; genetics; crossbreeding.

1. INTRODUCTION

Although the earliest objective of domestication of goats was for their meat, the nomadic and semi-nomadic pastoralists, and the sedentary agriculturists, realized the milking potential of these animals and began producing milk and milk products for their consumption (Nozawa, 1991). In developing countries, there are no religious prejudices against goat meat and often milk is used for domestic consumption while meat provides cash for the household (Taneja, 1982). In contrast, meat tends to be a by-product of the dairy and fibre industry in developed countries.

In the past, the majority of research has involved the use of the goat as an experimental animal. Thus meat goats have not been exposed to the scientific advances made in genetics, nutrition and husbandry that have been developed and increasingly applied globally to other livestock species. Currently, there is increasing evidence of goat improvement programs around the world. Potential improvement of morphological and production characteristics in the goat population through the application of quantitative genetic methodologies that have achieved success in cattle, poultry, pigs and sheep could certainly contribute to a dramatic increase in the efficiency of meat production. In this review, we summarize the research on the genetics of meat production in goats

2. GOAT GENETIC RESOURCES

The expansion of agriculture and the stock-raising culture has led to the development of three predominant types of goats (Bezoar, Savannah and Nubian) derived primarily from the Bezoar, Markhol and Ibex groups of wild goats. These animals have been classified into numerous indigenous populations, breeds, types and varieties according to their morphology, production and geographical origin. Mason (1988) and Gall (1996) have documented the origin, distribution, economic use and production characteristics of goats. Furthermore, a detailed description of a number of indigenous goats are presented in the Animal Genetic Information Bulletin published by FAO. These resources represent a colossal variation in the goat population that can be utilized in identifying desirable characteristics for use in improving the efficiency of goat meat production.

Most tropical breeds not specialized for dairy and fibre production are considered as meat goats, but they are often selected for reproduction and survival rather than growth and meat quality. In developing countries, usually meat breeds have a mature weight of 19 to 37 kg at 15 to 18 months of age (Taneja, 1982). This is in contrast to large breeds weighing 58 to 60 kg and dwarf breeds weighing 18 to 25 kg at the same age. Again, kidding interval has been reported to be relatively short in the more prolific small breeds.

3. GENETIC IMPROVEMENT

Genetic improvement has been successfully achieved by (i) selection among breeds with a potential for improved productivity and (ii) crossing breeds to take advantage of heterosis.

Considerable research has occurred in the genetic improvement of milk production through crossbreeding, selection and synthesis of new breeds. Results tend to support the potential milking ability of offsprings derived from the crossbreeding of exotic milk breeds that have demonstrated superior milk production in their environment and indigenous populations with inferior production in the local environment. There has also been a steady increase in research directed towards fibre production from cashmere goats. In contrast, serious effort in applying genetic principles to increase production efficiency is lacking in the meat goat. In the past 20 years, there have only been a few studies on the use of crossbreeding to improve meat production in goats.

In India, Acharya (1982) reported that the predominant meat breeds, the Sirohi, Kannaiada, Bengal and Assam Hill selected for adaptation were being evaluated for purebred and crossbred performance on the basis of growth, feed conversion and carcass characteristics. In Africa, the Bornu White, Red Sokoto, Small East African, Sudanese Desert and West African Dwarf have been evaluated for growth or carcass characteristics (Quartermain, 1991). In the United States, goat meat is usually produced from the Spanish breed types that makeup less than 20% of the population. Glimp (1995) describes prospects for improving productivity by crossbreeding with improved breeds and better nutrition. In the Norwegian specialized dairy goat farming, Asheim and Eik (1998) have suggested an alternative to the practice of culling the majority of kids shortly after birth. This includes the raising of all the kids for their meat. Thus providing an additional source of revenue in combination with cashmere fibre production. It should be noted that Shelton (1998) has reported a negative relationship between fibre and meat production under conditions where nutrition is a limiting factor. This tends to suggest that increased fibre production comes at the expense of meat production or requires a higher level of feed supplement.

The increase in the number of immigrants of ethnic origin in the developed countries has created a steady demand for goat meat and meat products. In New Zealand, goat meat from the Boer and Cashmere breeds, and their crosses was found to be similar in measures of instrumental tenderness, and sensory scores for juiciness as well as overall flavor intensity (Swan et al., 1998). In the same study, sensory attributes of patties made from goats and lambs were acceptable but distinguishable. Furthermore, panellists considered curries very acceptable suggesting the potential for their manufacture and promotion of goat meat based products.

3.1 Crossbreeding

It was widely believed that crossbreds derived from the mating of exotic breeds and indigenous goats would be more productive and suitable for local conditions. There have been considerable efforts to combine body size, growth rate and milk production of the exotic breed with the adaptation of the indigenous goat. Body conformation and size of the Anglo-Nubian breed have been introduced into small populations in the Bahamas (Wilson et al., 1980) and Fiji (Hussian et al., 1983). The European Alpine breeds, the Anglo-Nubian, the Boer and the Jamunapari are all recognized for their mature size. The contribution of these breeds on improving the potential for increased meat and milk production appears to be an attractive proposition. Crossbreeding has been rapidly achieved in a massive scale with the wide usage of artificial insemination to propagate the Saanen breed in Japan and Russia. Similar approaches have been used in developing countries with the wide spread use of bucks of a number of exotic breeds for mating with does from indigenous populations.

In various regions of India, studies on interbreed comparisons are usually based on small numbers and are often confounded with frequency of kidding, feeding and management systems. Acharya et al., (1982) reported that breed differences exist in body weight, reproductive performance and carcass characteristics of goats at different ages. The official Indian policy has been the grading up of inferior breeds with bucks of breeds that have exhibited a potential for increased productivity (Acharya, 1982). The Jamunapari and Beetal breeds have been utilized in improving productivity of indigenous goats. Occasionally physical replacement of the entire breed has been considered as an alternative to the grading up policy.

Taneja (1982) summarized the results of the All India Coordination Research Project on Goats. The Alpine, Saanen or Anglo-Nubian breeds have been crossed with Malaberi, Beetal, Assam Hill, Bengal and Jamunapuri breeds to increase growth and milk production. Large indigenous breeds have also been utilized for crossbreeding with smaller or medium-sized breeds. The Bengal, Marwari and Barbari breeds have been crossed with the Jamunapari breed. Jamunapari-sired offspring of the Black Bengal breed were found to be significantly heavier in body weight at 120 days of age than the smaller parent. In a program to produce larger meat goats by crossing the Beetal breed with higher reproduction and better adaptability with the smaller Sirohi does, the crossbreds failed to demonstrate any significant superiority over the Sirohi breed in body weight at 12 months. of age under range conditions (Misra et al., 1980). In the same study, mortality, feed efficiency and dressing percentage among the crossbred and parental breeds were similar ($P>0.05$). In contrast, under feed-lot conditions crossbreds were significantly superior in body weight. The advantage of crossbred offspring under abundance of feed has also been reported in Fiji where experiments with Anglo-Nubian crossbred kids showed that genetic differences in growth rate were more pronounced under conditions of stall feeding (Hussian et al., 1983). Crossbreeding studies have shown improvements in preslaughter weight and dressing percentage of Alpine x Beetal and Saanen x Beetal offspring. Under intensive feeding conditions at 5 months of age, there has been an increase in the preslaughter weight and hot carcass weight of Alpine x Beetal and Anglo-Nubian x Beetal crosses.

In Egypt, Anous and Mourad (1993) reported that offspring of crosses between Alpine bucks and Rove does showed significant estimates of heterosis in weight gain between 30 and 90 days of age, carcass yield, width, shape and internal fat. In Mexico, Montaldo, et al. (1995) reported that post-kidding body weight was 8% more ($P<0.05$) in offspring from local Mexican goats sired by bucks of the Nubian and Saanen breeds than the Toggenburg breed. Again, offspring from Alpine bucks weighed 18% more than those from Granadina bucks.

In a crossbreeding study of the German Fawn breed and Katjang goats in Malaysia, additive genetic effects for body weights at birth, 6 and 9 months of age and maternal genetic effect for weights until weaning were significant indicating large differences in growth rate (Hirooka et al., 1997). Although the size of heterosis estimates were small, for some traits, dominance and epistatic effects were important ($P<0.05$).

In Nepal, Sainju et al. (1998) reported that crossbred offspring from Khari goats sired by Jamunapari bucks were 3.5 kg heavier than either of their parental breeds. In another study, it was reported that Saanen x indigenous goat crosses were 7 and 13 kg heavier at 15 weeks of age than the Saanen and indigenous goat, respectively. Again, Barbari and Beetal sired offsprings of indigenous goats showed a tendency to grow faster up to 6 months of age, but later as the kids grew older, the indigenous goat exceeded their crosses in body weight.

In Sri Lanka, crossbreeding trials from 1983 to 1990 based on 2644 kids of the Boer, Jamunapari and Kottukachchiya breeds, birth weight was not reduced by *inter se* mating of 50% Boer crosses whereas backcrossing with the Boer bucks increased it (Premasundeba et al., 1998).

In the United States, Blackburn (1995) reported that the weight sold was higher in does of the Boer breed than the Spanish breed on high forage. In contrast, this advantage was reduced or reversed under medium or low forage conditions. Again, the number of kids sold per doe was similar under high forage whereas, Spanish goats were better under low or medium forage. In a study of 395 purebred and crossbred kids in Louisiana, from 1987 to 1992, additive genetic effects were small and negative indicating nonsignificant superiority of the Nubian breed in body weight and mortality over the Alpine breed (Gebrelul, et al., 1994). The Alpine breed was superior in maternal genetic effect over the Nubian breed for body weights at birth, weaning and market. Direct heterosis was significant and positive for body weights at birth and weaning but negative for kid mortality at 15 days of age. Maternal heterosis was in the desired direction for weaning weight and kid mortality from 16 to 90 days of age.

In addition, there have been a number of crossbreeding studies involving Saanen with the Sardinian, the Kilis in Turkey, the Damascus with the Anglo-Nubian and Jamunapari in Oman, the Katjang with the Saanen, Anglo-Nubian, British Alpine and Jamunapari in Malaysia, the Boer with the Small East African in Kenya and Malawi, the Criolo with the Saanen and the Barbados in Puerto Rico, the Nubian, French Alpine and Toggenburg in Venezuela, and the Anatolian Black with the Saanen and Maltese in Turkey (Quartermain, 1991).

There is often a problem in the interpretation of heterosis estimates from crossbreeding studies that have utilized bucks of exotic breeds to sire indigenous goats. In estimating heterosis, there is the confounding effect of genotype x environment interaction when one breed is at a disadvantage. This is more common when environmental and nutritional requirements are inadequate. As goat production tends to be concentrated in marginal land, mortality rate tends to rise. Without reciprocal crossbreeding studies, maternal effect has contributed to difficulties in the interpretation of heterosis effects. Procedures to exploit heterosis in the development of single or multi-breed crosses or composite breeds based on exotic germplasm have been outlined (Dickerson, 1969). In goats, further studies are necessary to obtain more precise estimates of recombination losses and epistasis. In exploiting heterosis for increased productivity, these estimates will help demonstrate the potential advantage either in developing composite population or specific crosses.

3.2 Composite population

The only well-documented case of goats selected for commercial meat production is the Boer breed. This breed resulted from the efforts made in the early 1920s by South African farmers from the eastern cape when indigenous goats kept by the Hottentot and Bantu tribe were crossed with imported Nubian and Indian goats (Skinner, 1972). Successive years of recurrent selection for size and conformation resulted in the creation of the Boer breed.

There has been frequent reference made to the proportion of exotic and indigenous breeds that need to be established while up-grading. A limited number of studies (García and Gall, 1981; Wilson et al., 1980) have failed to demonstrate any significant advantage in increasing the proportion of exotic breeding by backcrossing when compared to the productivity of the first cross (exotic x indigenous). In these studies, the superiority of the crossbred offspring over the exotic breed has been occassionally observed. Furthermore, there have been reports of poor reproductive performance in their offspring. Although the productivity of the first cross (F1) may be desirable, the cost of maintaining the parental populations increases the complexity of the breeding management. Alternate approaches utilizing repeated back-crossing with the exotic breed could eventually contribute to the loss of resistance to diseases and adaptation to local environments.

The most widely accepted reason for combining two or more breeds with different production characteristics, regardless of the contribution of heterosis is the additive genetic effect associated with the introduction of the exotic breed for improvement in productivity. Furthermore, the added benefit comes from the use of the indigenous breed for adaptation to local environments. The objective may lead to upgrading with the intention of breed replacement and ultimately leading to the development of a new breed.

Interbreeding of goats of a number of breeds in isolated environments has resulted in the development of small meat type breeds of Sri Lanka, India, Papua New Guinea, Fiji, etc., the various Criollo and Creole breeds of Latin America and the West Indies, the Spanish goats of the southwest U.S.A. and the Sem Raça Definidat goats of Brazil. In Australia and New Zealand, feral goat populations have been re-domesticated and are being developed for meat production. Successful new breeds that have been developed are the Anglo-Nubian, the Boer, the French Alpine, the Kilis, the La Mancha and the Peranakan Etawah (Gall, 1996).

3.3 Selection

The importance of environmental influences in the morphological and production characteristics associated with meat production are in general agreement with findings reported in other species of livestock. These studies on goats under uniform feeding and management have concluded that males are heavier than females, singles are heavier than twins that are heavier than triplets, and body weight tends to increase with age of dam to 5-6 years of age while decreasing at older ages. Genetic parameter estimates that have been published for goats are variable and subject to large sampling errors. A common practice in a number of studies on genetic parameter estimates, has been to pool the additive genetic variances derived from purebred populations with covariance derived from crossbred populations.

There have been a number of reports from India on estimation of the genetic parameters associated with various economically important traits in several breeds and their crosses. The details on the following estimates have been summarized by Acharya et al. (1982). In Alpine x Beetal and Beetal goats, the heritability estimates for age at first kidding were 0.48-0.56. In Beetal and Black Bengal goats, the heritability estimates for litter size were 0.09-0.15, respectively. There was no estimates reported on the heritability of livability in goats. The estimates of heritability for feed conversion were 0.23 and 0.04 based on dry matter and TDN, respectively. It has been suggested that the lower estimates for feed conversion and inconsistent correlations (phenotypic and genetic) with body weight excludes this trait for consideration in a selection index. Similarly, dressing percentage with a large heritability estimate was positively correlated with hot carcass weight. These findings suggest that body weight at 6 months of age could be used as a selection criterion in combination with age at first kidding to improve meat goats. In a recent feedlot trial with 117 kids lasting for 90 day, Misra (1995) reported that selection based on an index of body weight at 3 and 6 months and feed conversion improved the aggregate genotype.

In the Jamunapari breed, heritability estimates for body weights at 3, 6, 9 and 12 months of age were 0.30, 0.51, 0.23 and 0.31, respectively (Roy, et al., 1997). In the same study the estimates of genetic and phenotypic correlations among body weight at various ages were large and positive.

In Teddy goats under Pakistani conditions, the heritabiliy estimates for body weights at birth and weaning were 0.05 and 0.10, respectively (Tahir, et al., 1995). In West African Dwarf goats and their crosses, the heritability and repeatability estimates for body weight from birth to 150 days of age were 0.38-0.63 and 0.21-0.38, respectively (Ebozoje and Ngere, 1995).

In a study in Zimbabwe involving 2488 Dorper lambs, the heritability estimate was 0.19 for weaning weight, and 0.09 for conformation score (Buvanendran et al., 1992). Concurrently, repeatability estimates were 0.27 and 0.10, respectively.

In a large study from 1990 to 1993 involving 6247 South African Angora goats in 17 studs, estimates of direct and maternal heritabilities for body weight were 0.29 and 0.09, respectively (Snyman and Olivier, 1996). Estimates of phenotypic and genetic correlations between body weight and greasy fleece weight were positive.

The heritability estimates based on different estimation procedures were 0.16-0.33 for body weight at birth, and 0.16-0.35 at weaning (Niekerk et al., 1996). In another study with Boer goats, Schoeman, et al. (1997) reported moderate estimates of heritabilities for body weights at 6 and 9 mo., and one year of age. The estimates of genetic correlations between direct and maternal influences for body weights at birth and weaning were -0.31 and -0.15, respectively. It was concluded that during the selection of female Boer goats, the maternal component should be considered.

In Malaysia, in the German Fawn breed and Katjang goats, heritability estimates for body weights at birth, 6 and 9 months of age ranged from 0.18 to 0.33 (Hirooka et al., 1997). In a recent study of 838 common African and 688 crossbred kids sired by 16 French Alpine bucks (Mourad and Anous, 1998), estimates of heritabilities ranged from 0.68 for birth weight to 0.39 for body weight at 210 days, while phenotypic and genetic correlations among body weights were high and positive.

Selection depends on the ability to measure morphological and production characteristics and utilize the amount of genetic variation to achieve genetic response in the desired direction. Growth rate, feed conversion, reproduction and survivability have been identified as important in the selection for meat goats. In a study of longissimus muscle area and maximum depth measured using a real-time ultrasound on 25 male Alpine goat kids, it was concluded that selection of meat goats based on ultrasonic measurements would improve muscling (Stanford et al., 1995). The heritability of prolificacy though small is in the desirable direction. Therefore, while improving meat production the economic importance of fecundity should not be neglected (Devendra and Burns, 1983). Although no estimate of genetic response to selection has been published for meat goats, body weight appears to be moderately heritable and positively correlated with economically important traits. Thus body weight is effective in increasing market weight. Accelerated genetic response to selection can be achieved by increasing the intensity of selection in breeding herds with large effective population size and the tremendous amounts of variation known to exist. Use of herds with large effective population size, reduces the rate of increase in inbreeding and provides for a continued response to successive generations of selection.

4. FUTURE CONSIDERATIONS

The major advances that have been made in the last century in animal breeding have come from the application of quantitative genetic principles to the improvement of livestock and poultry. This has included breed evaluation, crossbreeding, selection and synthesis of new breeds for commercial production. In the last 20 years, genetic progress has been accelerated by fine tuning procedures, currently available in animal breeding. This includes the application of simultaneous genetic evaluation of sires, dams and their offspring based on multi-trait animal model which utilize mixed models methodology to obtain estimated breeding values, the use of restricted maximum likelihood procedures to estimate genetic parameters and the defining of optimal breeding objectives based on realistic economic values for traits used in selection. More recently, the promise of molecular methodologies has been enhanced due to considerable advances in microsatellite marker identification and the development of comprehensive gene maps. The improved and indigenous populations in developing countries need to be evaluated in relation to the socioeconomic value, constraints and limitations at a particular location. Application of the above mentioned technologies to the already identified and available global goat genetic resources may enhance the production efficiency of meat from goats.

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