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Contribution of Crossbreeding of Livestock in Upgrading Production and fostering Food Security

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ABSTRACT

Agriculture is the major economic activity in Kenya contributing up to 24 percent of the Gross Domestic Product (GDP) (GoK, 2014). According to Odhiambo et al. (2004), agriculture is the most important sector in the Kenyan economy. This is because it provides employment opportunities, source of foreign exchange earner, and food provision besides offering linkages with the other sectors of the economy. Moreover, agriculture is among the six key sectors identified to deliver a 10 percent economic growth per annum as envisaged under the economic pillar of the Kenya Vision 2030. The country aims at promoting an innovative, commercially oriented, and modern agricultural sector (Kenya Vision 2030). Animal genetic resources are used to accommodate both short and long term benefits for improved livelihoods. Structured breeding programmes provide a key to increase production levels and product quality, increase productivity and cost efficiency, maintain genetic diversity and support the conservation and sustainable utilization of specific breeds. For sustainable breeding strategies to take place there is a need for long term planning and commitment. For conservation or improvement of a breed or population for a given purpose the choice of breeding strategy is determined by a number of factors and is giving the framework for design of more detailed breeding programmes for specific populations.

Introduction

In sub-Saharan Africa, ruminants play an important role by converting forage to high value protein for human consumption. The consumption of meat and milk is expected to increase rapidly in this region (Herrero et al., 2014). Historically an increased demand for food of animal origin has been met by an increased number of animals, rather than by increased productivity from fewer animals. This has lead to negative effects on the environment, with effects such as overgrazing and soil erosion, and excess emissions of green house gases (Gerber et al., 2013). The Global Plan of Action for Animal Genetic Resources adopted by Food and Agricultural Organization of the United Nations (FAO) member states recognizes the role of animal genetic resources for food security through improved productivity while maintaining genetic diversity (FAO, 2007a).

A critical issue for conservation and genetic improvement programmes is the availability of supportive infrastructure. In low to medium input systems functioning infrastructure to support breeding activities is often lacking, or is underdeveloped (Herrero et al., 2013). In order for breeding programmes to succeed, infrastructure such as physical facilities, functioning livestock recording and genetic evaluation systems of some sort, are required. Notwithstanding the threats posed by increasing animal numbers on many livestock systems, the livestock sector is also facing the risk of losing biodiversity. Nearly 70% of the world's unique livestock breeds are found in developing countries (Hoffmann, 2010), and as many as 20% of the world's ~7,000 farm animal breeds are at risk of extinction (FAO, 2007b). For the developing countries there are two major reasons for the genetic potential of many of the indigenous breeds is not well utilized, resulting in low productivity, poor performance in the market place and ecological problems.

Livestock contribute in a number of ways to their owners and the nations where they are kept. Livestock in Africa contribute to approximately 22% of the agriculture gross domestic product (FAO, 2015). They contribute to rural development not just through the provision of food, but also to the general livelihoods (Chagunda et al., 2015a; Godfray et al., 2010). Livestock contribute with manure to be used as fuel, fertilizer and building material, hides and skins, draught power, employment, capital, social and cultural values (FAO, 2009c). Ownership of livestock is also considered a way out of poverty, not least in sub-Saharan Africa (SSA) (UN, 2014). Many groups of people in developing countries totally depend on their livestock for their livelihoods (Gerber et al., 2013; Homewood et al., 2009). Nevertheless, in SSA it has been estimated that 309 million livestock keepers live on less than 2 USD per day (Staal et al., 2009). SSA holds large numbers of livestock, almost 25% of the world's sheep and goat population and approximately 20% of the world's cattle population (FAO, 2015). Totally in Africa there are approximately 310 million cattle, 360 million goats, 340 million sheep, 34 million pigs, 23 million camels and 1.9 billion chickens (FAO, 2015). These numbers are very high, but many of these animals are not productive. Due to difficulties to compare animal numbers of different species in relation to their size, production or work potential, an exchange ratio has been established for transforming animal numbers of different species to so-called Tropical Livestock

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Units (TLU) based on an approximate average metabolic weight of adult animals of each species. In TLU the figures above corresponds to 155 million for cattle, 36 million for goats, 34 million for sheep, 7 million for pigs, 25 million for camels, and 19 million for chicken (conversion ratios: cattle 0.5, goat and sheep 0.1, camels 1.1, pigs 0.2, and chicken 0.01) (Njuki et al., 2011).

Literature Review

Livestock production systems vary in different areas and regions. Consideration must be taken to the ecosystem and that the animals must be adapted to the temperature, humidity and the environment where they are kept. Production systems can be categorized by the integration of crops, the relation to land, the agro-ecological zone, intensity of production and type of products delivered. In SSA the most common system is pastoral or agro-pastoral (Steinfeld et al., 2006b). Most systems are small scaled and family owned (Chagunda et al., 2015a). Dairy products are traditional consumption items with strong demand, and the temperate climate of the Kenya allows the crossbreeding of local cows with European dairy breeds to increase productivity (Holloway et al, 2000). The highlands of Ethiopia, which are very well suited for dairying, represent almost 50% (Winrock International 1992) of the total highland regions of sub-Saharan Africa. Milk plays a very important role in feeding the rural and urban population of Kenya and has high nutrition value. Milk is daily produced, sold for cash or readily processed. It is a cash crop in the milk-shed areas that enables families to buy other foodstuffs and significantly contributing to the household food security. Given the long tradition of using milk and milk products by the Kenyan society, there is no doubt that increasing smallholder dairy production and productivity would bring about a conspicuous impact on improving the welfare of women, children and the nation's population at large (MOA, 1998).

According to a recent livestock report prepared by the FAO (2003), milk constitutes a significant proportion of the value of all livestock food products in Kenya (about 56%), while livestock food products also constitute an important proportion of the value of total food products in the country (CSA, 2003; FAO, 2003). The annual contribution of ruminants to meat production in Ethiopia is estimated at over 3.2 million tones, representing over 72% of the total meat production. Cattle meat accounts for over 70% of the total red meat production and over 50% of the total meat output in Sub-Saharan Africa (EARO 1999).

According to FAO 1998, the total quantity of meat consumed worldwide rose by 45 million metric tons between 1983 and 1993. Total milk consumption rose by 57 million metric tons in liquid milk equivalents. In 1983 developing countries consumed 36 per cent of all meat and 34 percent of all milk-consumed worldwide. By 1993 those percentages had risen to 48 per cent and 41 percent, respectively. Between 1977 and 1989, level of dependency increased from 4.1 to 12.8% as a result of food aid, a World Food Programme (WFP) milk powder, and a level of dairy production development that has lagged behind the demand. These factors have eroded the contribution of milk production to food security (Staal and Shapiro 1996). Furthermore, imported milk powder, equivalent to about 11,213 liters of liquid milk per day, has a market share of 23% in Addis Ababa (Belachew et al. 1994). Since 1989, importation of WFP milk powder has decreased and nowadays it is not imported; however, importation of other processed dairy products, which are marketed in supermarkets, is increasing.

And due to foreign exchange constraints it cannot afford to continue importing dairy products so that developing domestic dairy sector and the expansion of the small-scale fattening are very crucial.

Cattle are kept for multipurpose. However, purposes vary with production system. Traction (males) ranked highest, followed by milk (females) and reproduction/breeding (males and females) in both crop-livestock and agro pastoral systems. Manure production also considered important by most crop/livestock and agro pastoralist farmers, but as secondary rather than a primary purpose. In contrast, reproduction/breeding requirements received higher ranks in pastoralist systems and, for female, requirements for breeding outranked the importance of milk production (Workneh, 2004) Livestock products, especially dairy, can make unique contribution to human nutrition of the poor in developing countries by providing micronutrients in bio-available form such as vitamin A, in addition to carbohydrates, protein and calcium. Thus, dairy producers by making more milk available for human consumption (Ahmed et al, 2003).

The basis of crossbreeding can be classified broadly into two types: additive and non-additive. The additive component is that which is due to the averaging of merit in the parental lines or breeds, with simple weighting according to the level of gene representation of each parental breed in the crossbred genotype (Swan and Kinghorn 1992). This additive component can be divided into individual and maternal additive genetic effects. The individual additive genetic effect is the contribution to offspring phenotype that is attributable to its own set of genes. Maternal additive genetic effects are defined as any contribution or influence on the offspring's phenotype that is attributable to its own dam (Maurer and Gregory 1990). Maternal effects can be classified into prenatal (e.g. cytoplasm of the ovum and uterine environment) and postnatal environment (e.g. milk production, method of rearing and/or mothering ability).

Heterosis is the non-additive effect of crossbreeding. It is the amount by which merit in crossbreds deviates from the additive component (Swan and Kinghorn 1992). Heterosis is usually attributed to genetic interactions within loci (dominance) and interaction between loci (epistasis). Heterotic effects can be classified into individual and maternal heterosis. Individual heterosis is the deviation (or superiority) in performance in an individual relative to the average value of the parental breeds, with maternal, parental or sex-linked effects playing no role. Maternal heterosis refers to heterosis in the population that is attributed to using crossbred instead of purebred dams and occurs due to the dam itself possessing heterosis.

When sustainably conserving, utilizing and improving farm animal genetic resources it is important to consider genetic diversity. Animal genetic diversity is commonly recognized as the observation of different forms and functions between species. One may also define the total genetic diversity in a trait within species as the variance of the phenotypes between breeds and between individuals within breed. The proportion of genetic variance due to between and within breeds is scarcely documented but a broad estimate indicates that about half of the variation in a trait within a given environment is due to differences between breeds and the other half due to within breed variation (Woolliams & Toro, 2007).

The opportunities for genetic improvement of a breed or population are directly proportional to the size of the genetic diversity (which can be seen as the standard deviation of the additive genetic variation of the trait in question).

Genetic diversity comprises not only variation in production and functional traits, but also the variation in the ability to adapt to different environments, including food and water availability, climate, pests and diseases (FAO, 2007a). For instance, some species and breeds perform better in low input environments while other breeds may perform better in intensive systems, a situation which well describes the concept of genotype by environment interaction. The within breed diversity is usually related to the rate of inbreeding in a breed. To keep a breed vigorous and sustainable it is necessary that the population is not too small or too inbred. Inbreeding is the result of mating related animals. In a small and closed population, all animals in future generations will be related to each other to some extent and for every generation the level of inbreeding and homozygosity will increase. The rate of inbreeding in animal breeding is related to the effective population size. Declining effective population size leads to increased rate of inbreeding. It has been suggested that for persistence of a population, the minimum effective population size should not be smaller than 50 breeding individuals (Rai, 2003).

An effective population size of 50 corresponds to a rate of inbreeding of 1.0% per generation (Maijala, 1999). With future changes in climate and markets, and their changing needs, it is important to ensure that a broad diversity is available. Livestock keepers have diversified species over centuries, into thousands of breeds. However, currently the trend is towards uniformity and large high output monocultures of production systems due to globalization of livestock inputs and markets (FAO, 2009a). Traditional production systems with locally adapted breeds are becoming marginalized compared to high output breeds. Most breeds may have a potential importance in the future, and should therefore be conserved. They must, however be competitive on the market or contribute to livelihoods in other ways. To cope with the changes and food security it remains vital to maintain and increase the productivity of livestock. More broadly, genetically diverse livestock populations provide society with a greater range of options to meet future challenges (FAO, 2007b). When breeds are lost genetic diversity declines. For livestock stakeholders to know the status of breeds, the Global Databank for Farm Animal Genetic Resources of FAO classifies breeds into one of the following seven categories: extinct, critical, critical-maintained, endangered, endangered-maintained, not at risk, and unknown (FAO, 2007b; FAO, 2000)

Crossbreeding may either be to exploit the positive effects of heterosis when crossing two or more breeds, or to incorporate superior genes from one breed into another. This can take many forms. For continuous exploitation of heterosis a two- or three-breed rotational crossbreeding programme may be desired. Crossbreeding can also be used to upgrade one breed with another superior breed that also fits the environment. The issue is what alleles and traits that are transferred to the remaining breed and what alleles are lost. Crossbreeding is often used to produce a terminal cross, e.g., for production of animals for slaughter and the heterosis is exploited in the end product. If the first generation of progeny, the F1-animals, is clearly superior to another breed by having a desired mixture of traits or alleles, even without the heterosis effect, and if a consistent crossbreeding programme is not suitable, matings of the crossbred animals may eventually lead to formation of a new “synthetic” breed. However, any breeding programme requires infrastructure for recording of animal identities and pedigrees of the whole population (Mueller et al., 2015). If the crossbreeding is not controlled this may lead to “indiscriminate” crossbreeding with loss of important animal genetic material (Taberlet et al., 2008). The design of a breeding programme may differ depending on the availability of livestock recording and supportive infrastructure.

In SSA there is often a limitation of available infrastructure for keeping records and pedigrees of the animals. If a large part of the population is recorded, the selection programme may include all recorded animals as potential breeding stock. If livestock recording is lacking the selection could for example be organized in specific nucleus herds from where selected animals or genetic material (e.g., semen) are transferred to a lower tier (commercial level) for multiplication of desired genotypes. Livestock recording is in this case limited to the nucleus herd. As regards reproduction methods natural matings is the most common in SSA, but it may be replaced by artificial insemination, especially in dairy cattle, where a cost effective supporting infrastructure is often available. This will however depend on infrastructure available and the species to be used. In advanced systems, embryo transfers may be an option for use with elite animals. In the very advanced systems, where livestock recording is well developed and genomic selection is being practiced, gene-sequencing results can be related to breeding values based on phenotypic information of large reference populations.

Livestock production has become a main sector in poverty reduction policies in developing countries. Blench et al., (2003) studied on the role of livestock production for the poverty reduction strategies of sixty-one developing countries as well as issues affecting livestock development in relation to poverty alleviation, which indicated that most poor people in those countries lived in rural areas where agricultural production was the main activity. Governments considered the roles of the agricultural sector in poverty reduction, but contribution of livestock was not reasonably acknowledged, although they knew that livestock had an important role to poverty alleviation through national data. Pica-Ciamarra (2005) stated that the governments in developing countries were using livestock production as a way to carry out poverty reductions. They had policies to “kick-start domestic market” and “expand livestock markets.” Why did they assess livestock production as a sector for poverty reduction? In a study of Preston (1977), he claimed that objectives of livestock production in developing countries included producing meat and eggs to enhance nutrition and satisfy food demands for local people; saving and/or earning foreign exchange; creating more employment; improving living standard; contributing to regional development; and developing systems in terms of biological, economical and ecological contexts.

In the article “why keep livestock if you are poor” of Kitalyi et al., cited by Owen et al., (2005), they explored that the role of livestock has been to provide food for people over hundreds of years. The ancients raised livestock to address the problem of unpredictability of food supply associated with unpredictable weather.

Now, livestock keeping of the poor is related to food security in terms of protein supply sources as well as essential micronutrients and energy supply sources. They use animal products especially small animals such as poultry for food or might sell animal products to buy cereals in order to provide nutrition for the daily meals. They demonstrated that poor people who raised livestock tended to consume more livestock products than the poor without raising livestock. Moreover, Kristensen et al., (2004) argued that food requirements increased day by day as a result of the increase in population, household income and urbanization. Livestock played a key role to satisfy this requirement. One livestock project that was described in the paper showed that livestock products consumption of farmers in the project increased two times compared to farmers who were not members of project. Fresco & Steinfeld (1997) explained that livestock related directly and indirectly to three aspects of food security, which were food production, stability of supply and access to food. Livestock provided high animal protein products; supported draught power and manure; and created income and stored wealth for households.

Earlier Goat Breeding Initiatives (1980S-2005)

In 1980-1992, the government of Kenya implemented the development of a new goat breed, the Kenya Dual-purpose (meat and milk) goat (KDPG), with support from the USAID-Small Ruminant Collaborative Research Support Program (SR-CRSP) (Peacock, 2008). The KDPG was a synthetic breed that was designed to be suitable for smallholder farming systems in East Africa (Peacock, 2008). The crossbreeding mechanism was however, complex, and implementation faced logistic obstacles leading to the end of the initiative (Peacock, 2008). The synthetic KDPG breed was developed by crossing two local (Small East African and Gala) and two European breeds (Toggenburg and Anglo- Nubian) (Peacock, 2008). The breeding station was run by the government and based in Naivasha. The goats were then tested in another region of the country, Western Kenya, and performance was poor (Peacock, 2008). The distribution of crossbred goats in this project was market driven: the government planned to contract commercial farmers to reproduce the breed (Peacock, 2008) for sale, with the market regulating price based on demand and supply. Eventually, donor funding for the project ended, with very few KDPGs currently in the country (Peacock, 2008).

From 1983-1989 the Kenya Ministry of Livestock Development, supported by the British Government's Overseas Development Agency (ODA), attempted to develop a different type of dual-purpose goat for arid and semi-arid areas. This initiative took off from a well-funded station but did not materialize as the manager left the station as soon as project funding ended. The goats also developed beznoites disease (Peacock, 2008).

In the 1980s and 1990s the German Government, through GTZ, funded two major goat-breeding initiatives in Burundi and Kenya (Peacock, 2008). The project in Burundi project pioneered the buck station as an economical way of breeding (Peacock, 2008). The source of the breeding bucks however was a breeding station managed by the project, which imported German Alpine goats and unfortunately introduced the disease Caprine Arthritis Encephalitis (CAE) into Burundi (Peacock, 2008). Once the project ended, farmers were not able to replace their bucks, leading to breed dilution (Peacock, 2008). The goat breeding project in Kenya was established using Alpine bucks imported from Germany without females until towards the end of the project when 10 females were imported. Farmers in the Meru region where the buck station is based have upgraded their goats but the lack of a secure supply of locally bred replacement bucks could threaten sustainability of the project (Peacock, 2008). Over the past 30 years NGOs have introduced European dairy breeds on relatively smaller scales compared to the government projects described above. Many NGOs have also distributed local goats as part of development or rehabilitation programs especially following displacement due to droughts, or war (Peacock, 2008).

These small-scale breeding programs have however not brought about beneficial impacts to their full potential because they have not been delivered with accompanying improvements in health care, feeding, and overall management needs required (Peacock, 2008). These early breeding interventions also have the inability to ensure a secure supply of the improver breed as a major weakness, compromising the sustainability of the initiatives. Similarly, the large-scale donor-supported programs, implemented by governments have not been able to proceed after withdrawal of donor funding. They have also not been able to overcome logistic difficulties of successfully handing over breeding management to communities in a way that enables them to carry on with the initiative independently and productively.

Newer Initiatives 2007-Present

Proceeding from the earlier decades of failure and learning, many NGOs, including, but not limited to FARM-Africa and Heifer International, are now engaged in community-based goat breeding programs designed with significant improvements over the earlier initiatives, and are proving to be relatively more successful (Ogola et al, 2010a). The first focus in these newer initiatives is making the goat breeding programs as participatory as possible by involving farmers early on in the planning through to the implementation stages. Farmers are encouraged to organize and self manage through cooperatives or general groups (such as women's trade groups, female breadwinners' groups, etc.) through which breeding interventions are introduced and carried out, and act as implementation partners rather than recipients of intervention (Peacock, 2008). These farmer groups strive to serve as all-round support systems to fully realize the benefit from goat breeding systems. Organizing into farmer managed groups provides a venue for the pooling together of human, financial and other in-kind resources such as credit for purchasing goats and insurance systems, information translation and record keeping assistance for illiterate members, use of local skilled members such as PhD and MS students within the communities, communal strategizing for goat feeding and watering, and dissemination of general information on health care and accessing extension services (Peacock, 2008). Social learning is an aspiration of new goat breeding initiatives, whereby social learning involves learning within a community context with attention to peer communities, history, and local knowledge (Wenger 2009). Peacock (2008) noted, ". . . attitudinal changes may need to take place among staff of implementing partners" (p. 229), in order to fully realize the potential of the breeding project. The small, localized scale at which community breeding projects operate allow for clarification of responsibilities and roles among community members, and between community members and partnering agencies.

To address the challenges of accessing the improver breed and sustaining buck stations, the community-based approach to breeding selects a buck station within reach by those targeted in the breeding intervention, preferably on a selected set of members' farms. A differential fee is charged for each mating—lowers fees for those targeted and higher fees for those interested but not in the target group(s) (Peacock, 2008).

Current community-based approaches to goat breeding also differ from earlier goat breeding systems in their emphasis on feeding and health care of goats as part and parcel of the breeding system, and not as separate or non-related aspects. Rather than stopping at establishing mechanisms for distribution of goats to communities, this approach gives significant consideration to the complete suite of animal management needs. Housing of goats is encouraged, and the cooperative nature in which the projects are implemented enables communities to strategize on communal feeding arrangements and on gathering material for construction of housing units, feeding pens, etc (Peacock, 2008). Additionally, the breeding systems are increasingly coupled with improved crop- farming systems to provide food for goats and feed for households (Lenné and Thomas, 2006).
Unlike earlier donor-government large scale predetermined projects, small-scale community breeding projects are flexible enough to allow for targeting specific segments within a community, e.g. women-headed households, households affected by HIV/AIDS or lowest income households (Peacock, 2008). At this scale, the community-based approach allows for collection of household-specific baseline data before commencing on an intervention. This in turn enhances chances of monitoring any real impacts the projects are having, especially on poverty. The targeting and selection process is small and localized enough and is carried out with local leaders from the community and governing agency to ensure that the process is not coopted by local elites. The scale is also small enough to take into consideration individual circumstances such as livestock ownership, landholding size, quality of house, number of dependents, engagement in other employment, among others (Peacock, 2008), and to use this data in further modifying implementation steps accordingly.

Conclusions

Crossbreeding between highly productive and adapted breeds can improve overall performance. However, if crossbreeding is indiscriminate and uncontrolled, it may result in reduced productive advantage. In the starting phases of a crossbreeding programme, performance is always improved due to the heterotic superiority of the first cross. Thereafter, if the programme is not checked, the productive advantage may be reduced either because of recombination loss that leads to breakdown of the heterotic superiority in subsequent generations or upgrading to high levels of exotic blood without changing the environment. This leads to insufficient adaptation, which is manifested in the decline in performance. Cunningham and Syrstad (1987) reported a linear improvement in almost all performance traits up to the 50% B. Taurus inheritance. Beyond 50%, there was a slight increase in calving interval, but no clear trend in the other traits. Madalena et al. (1990a; 1990b) found increases in performance for all milk, reproductive and calf traits up to 62.5% B. Taurus inheritance, after which performance began to decline. In a comprehensive review of 80 reports from Africa, Asia and Latin America, Rege (1998) reported an improvement in milk yield when the proportion of exotic blood increased from 0 to 50% and a constant level between 50 and 100% exotic inheritance. A similar trend was observed for age at first calving. Lactation length increased over the entire range of exotic grades, although with 'up-and-down swings'. For calving intervals, the shortest were observed for animals with 50% exotic genes and were longer both for animals with lower or higher exotic inheritance

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