RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
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Adapting Selection Schemes for Indigenous Cattle Improvement in Sub-Saharan Africa-A Review

Godfrey L. Chasama., Jestina V. Katandukila, and Aloyce Hepelwa

ABSTRACT

Livestock keeping is an important livelihood option in the tropics and cattle play the major role. For sub-Saharan Africa, most of the cattle kept are of indigenous type exhibiting low to medium production coefficients. After realizing low impact with crossbreeding in improving their productivity during the first three quarters of the 20th century, many sub-Saharan Africa countries turned to adoption of selection schemes during the last quarter of the century. However, many countries still haven't realized active operation of selection schemes for indigenous breeds improvement. Major constraints are unsustainable financing, weak coordination, inadequate policy support and weak technical foundation for animal breeding. Existing infrastructure networks are not supporting extensive operation of selective breeding. Systematized pedigree and performance data recording is lacking in many countries. Important guidelines for streamlining implementation of breeding operations among actors are not in place. Strategies for adapting selection schemes in sub-Saharan Africa should target exploitation of unique potentials of indigenous breeds and focus to the improvement of their productivity while also maintaining their adaptability. From the prevailing conditions, considering immediate transformation to farmer-operated central nuclei is not recommended in structuring the scheme. What is recommended is to start with dispersed village-based group pre-nuclei which are backed by institutional central nuclei. Important strategies in enabling effective operation with such structured schemes include evolving guidelines for implementing selection in terms of defining breeding objectives, increasing involvement of farmers, strengthening coordination of animal breeding, promoting inter-institutional collaboration, and considering some more government financial support.

Keywords: breeding challenges, breeding strategies, selective breeding, shorthorn zebu.

Submitted: December 7, 2022

Published: January 9, 2023

ISSN: 2684-1827

DOI: 10.24018/ejfood.2023.5.1.622

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I. Introduction

Livestock production is an important livelihood option and development pathway in the developing world [1]. In most of sub-Saharan Africa countries cattle constitute the backbone of livestock industry [2]. Over 80 percent of the cattle in the region belong to indigenous breeds [3]. The cattle are utilized as a source of meat, milk, hides, manure draft power and other non-conventional utilities [4]. However, indigenous cattle of the region have evolved to be exploited more for beef [5]. In Tanzania for example, 33% of livestock keeping households obtain their highest income from beef cattle which also contributes over 40% to the country's livestock Gross Domestic Product [6].

There has been an ever-growing concern that, in pastoral and agro-pastoral systems under which most of the sub-Saharan Africa cattle are kept, beef productivity has been declining with depleting grazing resources [7]. Meanwhile, increase in urban population and disposable income triggers increase in demand for beef, being one of the major animal protein sources [8]. Fattening as a short-term feeding intervention for improving productivity is highly challenged by the rapidly rising concentrate feeds' cost [9]. On the other hand, improving productivity via plane of nutrition through pasture establishment without improving genetic potential appears to be economically lowly viable with most of indigenous breeds because of their low production coefficients [10]. A critical outlook indicates the need to use cattle with higher genetic potential for both growth and feed utilization, in order to improve production efficiency [6]. This is possible through breeding which has selection and crossbreeding pathways.

Considerable breeding interventions have been implemented for over a century in sub-Saharan Africa [11]. To a greater part the past cattle breeding initiatives in the region, which were initiated during the beginning of the 20th century capitalized on crossbreeding [11]. Possibly this was because of the general conception that the pathway is relatively faster in making genetic improvement. However, to a larger extent un-sound outcomes were encountered with

the approach in terms of realizing genetic gain with sustainability, and criticism on causing genetic dilution has been high [12].

Selection pathways on the other hand is genetically less erosive and selection schemes have shown to be impactful in a vast of tropical countries in Australasia and South America [13]. In sub-Saharan Africa however, despite adoption of selection schemes being widely attempted in the past four decades, actively operating selection schemes are still rare even for populous breeds [14]. One of these is Tanganyika Shorthorn Zebu (TSZ) breed which is considered to have high potential for selective breeding from its high within breed diversity [15]. The planning of development of a selection scheme for this breed can benefit from lessons that can be drawn from selective breeding experiences from similar farming systems in the tropics. This review was conducted with the objective of exploring ways of mitigating constraints to operation of selection schemes for beef cattle improvement in sub-Saharan Africa with focus to TSZ cattle breed which is native to Tanzania Mainland.

II. Materials and Methods

Review of relevant literature was conducted to gather information for exploring potential interventions for beef cattle breeding industry with focus to selection pathway in sub-Saharan Africa. Search of relevant sources was done in accordance with the basic reviewing principles described by [16] as follows: reflecting the study purpose, recognizing authority, proven effectiveness of the content and ensured reliability of the source. Papers (from journals and conference proceedings), scholarly reports (theses and dissertations) and documents (from governments' ministries and organizations) related to the topic were searched from the internet using search engines. Main keywords were zebu cattle, selection schemes, beef cattle improvement and breeding challenges.

III. Data analysis

Relevant information gathered was summarized and synthesized into past experiences on operation of selection schemes for beef cattle and challenges to adoption of selection schemes in sub-Saharan Africa. Subsequently, based on the literature information captured, views on needed interventions for adapting selection schemes for beef cattle improvement in sub-Saharan Africa were presented. Finally, implications on developing selection scheme for TSZ breed under agro-pastoral system of Tanzania were outlined.

IV. Results

A. A Global Perspective on Operation of Selection Schemes for Beef Cattle

As it is the case with other livestock species, Europe, North America and Australian countries have made leading progress in beef cattle breeding [17]. Conditions regarding availability of advanced technologies, well developed breeding criteria, financial and human resources capability of governments which also recognized well the contribution of farmers' herds in national beef production, contributed much to development of livestock breeding [18]. One development facet is the evolution of well-structured breeding schemes which imparted efficiency in breeding operations and sharing of genetic gain among breeders, including farmers [19].

Brazil is the country with the biggest beef cattle industry in the Latin America and has had successful breeding programs for beef cattle [20]. Most of its beef cattle are of Zebu type, which occurs in fifteen breeds, all with specific open-nuclear breeding schemes operating selective breeding using pedigree and performance data as well as genomic selection tools [20]. In addition to the breed specific schemes there is a national breeding program which plays roles of overseeing and coordinating the operation of all the breeding schemes in the country [20]. The government has made significant financial support especially at establishment but exploitation of multi-stakeholder collaboration in implementing breeding programs stands as another important financing and technical backstopping strategy [21]. Farmers are well organized for collective actions in animal breeding, a feature which has boosted much the accessibility of farmers to utilization of modern breeding technologies [20].

In most of Asia and Pacific countries beef cattle breeding industries are not advanced as in Latin America, although for India technological advances are not quite different from Latin America countries [20]. Nucleus breeding structures for beef cattle are found but animal recording and data feed-back is still not going that far beyond government farms and institutions [22]. Few beef cattle keepers have been integrated into the use of genomic selection tools, but utilization of Artificial Insemination (AI) is common among farmers [23]. Another constraint to development of beef cattle selection schemes in Asian countries is limited government commitment to long-term breeding programs [22]. This is considered to be mostly a consequence of unstable livestock breeding policies which lead to limited advocacy for financing livestock genetic improvement [22]. Lack of strong linkage among stakeholders of beef cattle breeding, even between government ministries, institutions, agencies, and departments is another factor pointed-out by [22] to have hampered the development of selection schemes for beef cattle in Asian countries.

Operation of selection schemes has had less success in sub-Saharan Africa than elsewhere in the world [24]. Attempts to introduce selection schemes for beef cattle in sub-Saharan Africa, which were initiated during 1980s in most countries, are generally criticized from using conventional approaches which under African operational circumstances are non-fitting [25]. In the region breeding stations are few and inadequately equipped, financing from governments is not sustainable while adequately facilitative and stable breeding policies are also not in place [14]. The problem of financing beef cattle breeding in the region is aggravated by the underdevelopment of private sector and weak collaborations among government entities which have a stake on beef sub-sector development [19]. Data recording systems are not yet instituted in many sub-Saharan Africa countries and thus extensively recorded pedigree and performance data are unavailable, making estimation of

genetic and phenotypic parameters for guiding breeding decisions infeasible [26].

B. Challenges to Operation of Beef Cattle Selection Schemes in Sub-Saharan Africa

The major challenges to adoption of selection schemes in sub-Saharan Africa are presented schematically in Fig. 1. Core impediment to operation of selection schemes in the region stems from lack of sustainable financing [3]. Many countries are still relying on developing breeding infrastructure using funds from donors which have tended to be of short-term and focusing infrastructural development of institutions only [3]. With in-existence of breeding policies there has been inadequate advocacy for animal breeding financing as the issue of animal breeding has been receiving low attention in comparison to other livestock development issues like control of infectious diseases, protection of grazing and watering resources and development of marketing infrastructures [27]. Presently few governments in sub-Saharan Africa allocate sufficient budget for developing animal breeding [14].

Consequent to inadequate financing, enabling environment in terms of facilitation for extensive performance recording, animal evaluation and germplasm dissemination has been lacking [14]. According to [18], many breeding industries in Africa are still not supported by adequate infrastructures and technologies to operate viably efficient breeding methods like progeny testing, Multiple Ovulation Embryo Transfer (MOET), and Marker Assisted Selection (MAS). Consequences of low infrastructure are exacerbated by high assumption of conventional breeding approaches and lack of simplicity in operations and arrangements to cope with the existing conditions [28].

Failure to replicate Community Based Organizations for Genetic Improvement of Livestock (CBOGI) was another shortfall in development of selection schemes in Africa [29]. Because of this, involvement of farmers in the designing and execution of breeding initiatives has been low in many sub-Saharan Africa countries [30]. The failure to secure adequate farmers involvement occurs with lack of critical analysis of their breeding needs and inadequate representation in planning breeding activities which culminated to breeding programs which don't align well with their needs and values [31]. With limited involvement of farmers, mitigation of the challenge of limited financial resources through cost sharing among farmers has remained less exploited in many countries [19].

Lack of strong technical support for livestock breeding was another challenge in past breeding initiatives in Africa [14]. Stud books haven't been established in many countries [32] and breeding objectives for guiding the structuring of animal performance recording, evaluation, selection, and mating systems haven't been defined for many indigenous breeds [14]. The issue of animal breeding touches stakes of several government institutions and non-government organizations but the division of accountability and mechanism for coordination have not been in place in many African countries [19]. This mostly occurs because they haven't clearly stipulated mandates and roles that different government departments and institutions have to play in availing and facilitating farmers' access to animal breeding services [14]. This rendered livestock breeding initiatives un-coordinated and somewhat haphazard operation ending up sometimes in realization of genetic losses instead of genetic gains from indiscriminate breeding practices [14].

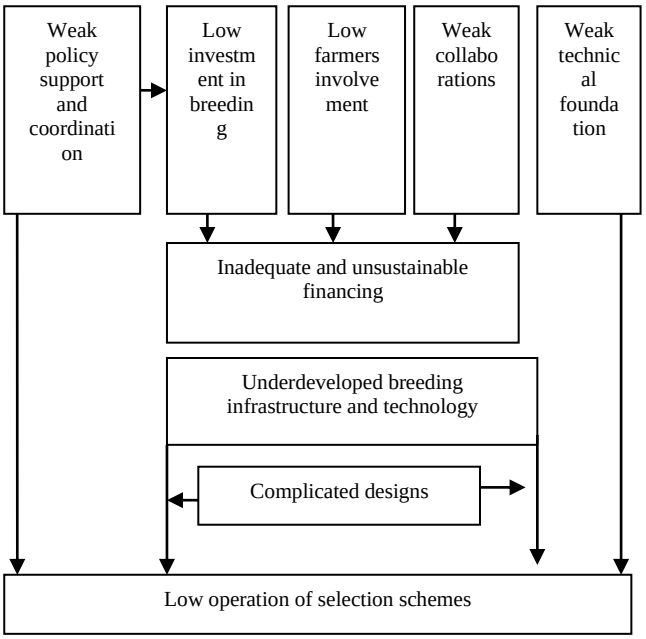

Fig. 1. Major constraints to operation of beef cattle selection schemes in sub-Saharan Africa.

V. Discussion

There is a consensus that the foundation for developing impacting breeding programs for beef cattle in sub-Saharan Africa has to be built upon implementation of strategies focused to develop indigenous breeds [33]. That has to be done with the inclination of improving their productivity while also conserving their adaptability [34]. It is however important to point-out from the beginning that, this argument echoes for giving due emphasis to selection within breeds as a strategic option for genetic improvement but doesn't criticize or discourage for exploitation of crossbreeding strategy. With effective mechanisms for control of *taurine* blood within recommended levels, it is quite possible and even quicker to upgrade performance credentials of one indigenous breed using another superior local breed or even an exotic one while also allowing conservation of their adaptability [19].

To a larger part, past experiences show that unsustainable financing, which featured as the core constraint (refer Table I), can in one way be mitigated through increasing involvement of farmers in planning and implementation of genetic improvement programs. It is a recommendation of [18] that, the involvement mode has to be direct, of all stages and enable the farmers to have adequate ownership of the breeding initiatives. Such engagement of farmers in livestock breeding can be effectively achieved with the existence of farmers' organization as breeders' association which have had low pace of formation for beef sub-sector in sub-Saharan Africa [19]. It is as such important to stimulate and facilitate the replication of CBOGI for beef cattle in sub-Saharan Africa. Logically, extension and cooperatives development departments in local governments and

development partners wherever are present have important roles to play towards realizing this in respective countries.

Objective determination of preferential traits involving relative importance quantification, which has been shown to be more practical for addressing aesthetic traits in breeding programs, is not yet done in many sub-Saharan Africa countries [31]. There is much qualitative information on socio-economic values of indigenous cattle of the region, but they have made low contribution in inputting insight needed for strategizing engagement of indigenous cattle keepers in planning and implementation of breeding programs [35]. The patterns of valuing utilities from indigenous cattle in traditional systems are complicated and choices of breeding animals involve trade-offs among valued traits, a condition which requires explicit estimation of preferences [35]. Therefore, where it has not been done, quantitative determination of preferential traits owes to be among priority gaps to fill. The results of such analyses have to constitute the basis for framing strategies for stimulating higher impetus in replicating CBOGI as farmers views and perceptions on cattle improvement are captured and integrated into breeding programs.

Promotion of multi-stakeholder collaborations is considered a potential strategy for mitigating the constraint of inadequate financing [21]. Exploitation of this requires the establishment of strong linkages between and among all potential stakeholders, especially those in vicinity [36]. With good coordination and networking this prevents antagonisms and duplications in roles played by them, and thereby allows for distribution of limited resources to a wider scope of activities [27]. These in turn can enable higher scales of operations and bigger impacts with the same resource base [21]. In most sub-Sahara Africa countries private sector is lowly developed for beef cattle breeding [20]. For that reason, the promotion of collaboration insisted here is meant among public institutes and what is required in essence is having in place stronger inter-ministerial and inter-institutional coordination with coordination and linkage mandate for animal breeding.

The primary technical foundation in breeding is having in place a breeding objective [37]. Principally breeding objective owes to constitute the framework from which key breeding policy guidelines are to be derived [37]. It is therefore important for responsible ministries to develop breeding objectives of specific cattle breeds that can be used to develop selection criteria in order to have nationally streamlined animal recording, evaluation, ranking and selection which can also lead to realization of optimum genetic gains [19]. The role of policy in developing animal breeding has recently been recognized and during the past decade many African countries legislated breeding policies [14]. However, many countries have faced difficulties operating such policies or haven't made equitable progress because they were defined empirically [14]. There is a need to consider re-definition of breeding objectives and recommending policy reforms during policy reviews. Policies should also be used efficiently as tools for spearheading and advocating animal breeding to improve government budget allocation and enforce pertinent guidelines to coordinate actors and operations in breeding industry.

TABLE I: KEY STRATEGIES FOR MITIGATING CONSTRAINTS TO OPERATION OF SELECTION SCHEMES IN SUB-SAHARAN AFRICA

Constraint	Mitigation strategies	Potential actors
-Limited government financial support	-Legislating breeding policy and advocating sufficient budget allocation for breeding	-Central governments in responsible ministries
	-Organizing farmers for higher involvement and cost sharing	-Local government authorities
	-Attracting and promoting collaborative animal breeding initiatives	-Central and local governments, Research Institutes and Private sector
-Low policy support and lack of coordination	-Reforming breeding policies and enforcing pertinent guidelines among actors in breeding industry.	-Central governments in mandated ministries
	-Incorporating coordination mandate in ministries	-Central governments in mandated ministries
-Low farmers involvement	-Facilitate formation of CBOGI	-Breeder farmers, Local government authorities and Research Institutes
-Weak technical foundation	-Simplifying breeding approaches to cope with existing infrastructure, technology and technical expertise	-Research institutes
	-Utilizing genetic parameters estimated from related breeds in similar farming systems.	-Research Institutes

While the operation of selective breeding in some tropical regions outside Africa has developed to the stage of using sire referencing schemes, which involve the use of Best Linear Unbiased Prediction (BLUP) in animal evaluation [38], in many sub-Saharan Africa countries, even performance recording is still confined within government institute farms [20]. To be realistic it is important to consider undergoing a transition while heading to such a development stage. This is because obviously it will take time for sub-Saharan Africa countries to be installed adequately with such advanced breeding technologies. It is more or less equally important to acknowledge that there is considerable potential to impact genetic gains from community-based breeding by targeting mainly exploitation of natural mating and Artificial Insemination technologies at present [27]. This owes to be one of the first realities to bear in mind towards adjusting conventional approaches to simplicity so as to cope with the prevailing infrastructures in sub-Saharan Africa as suggested by [3]. However, validation of more advanced breeding technologies in the region is important and should be conceived as an important competing strategy for breeding industries in the future.

Fig. 2 is a presentation of the scheme structure that can be recommended to start with. The structure has three tiers which are institutional herds making the central nucleus, organized breeder farmers pre-nuclei dispersed around institutional central nuclei which have to play role as the multipliers, and commercial farmers who buy germplasm from the pre-nuclei for final use of breeding in their herds (refer Table II). Pre-nuclei are therefore the non-existing components which for that case are to be formed to play the role of linking the nuclei and commercial farmers. Seven key steps (Fig. 3) are to be passed to enable taking-off with

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the recommended scheme structure. The first is developing breeding objectives and translating them into breeding guidelines as selection criteria for implementing selection in the two inner tiers. The second is developing structures and installing required technologies as determined by the planned breeding operations reflecting the breeding objectives. The third is formation of CBOGI-pre-nucleus through organization of progressive farmers in breeding. The fourth is stocking nucleus and pre-nucleus with adequate quality animals. The fifth is putting in place animal recording and evaluation system. The sixth is implementing selection and the seventh is multiplying and disseminating germplasm. While all these are dealt with it is important to observe simplicity of breeding operations to cope with the prevailing conditions, ensure adequate involvement of farmers and secure basic financing for key breeding activities from governments.

Tanzania has public livestock research centers, multiplication units and ranches capable of hosting nucleus operations where intense selection based at least on Artificial Insemination can be run [6]. These make the first foundation upon which initial central nuclei can be established at minimal investment [22]. What is primarily needed is expanding their scale of operation by re-stocking them with adequate stud herds, re-tooling with basic equipments and instituting systematic animal performance recording and evaluation systems to enable objective ranking of animals and selection [39]. Installing such stations with capacity for Artificial Insemination is highly recommended in order to improve selection intensity and speed up genetic gaining [20]. Dissemination of germplasm is however recommended to be in forms of both semen and young bulls for the sake of adapting to varying needs for operational simplicity [32]. Considering the extensive nature of the production system and sedentary mobility of cattle herds, the pre-nucleus is to be located where beef cattle herds are clustered to facilitate accessibility of most if not all farmers to germplasm supply. At the pre-nucleus farmers will have opportunity to select also for non-conventional traits on the dams' lines so as to address traditional needs of indigenous cattle breeding. This is insisted to be done so that the delivered final genotype caters for improvement of both conventional and un-conventional traits. That is also very important for ensuring acceptability of delivered germplasm among commercial farmers and at large economic sustainability of the prospective selection schemes [19].

Both activation of central nuclei and initial establishment of pre-nuclei have financial implications at the beginning, although they can be low with simplified designs. In that regard, what will be needed also at the beginning for the country's government to launch selection schemes is to make considerations to finance needed initial investment in infrastructure and equipments to enable taking-off [19]. Logically the activation of central nucleus has to be the role of the Ministry of Livestock and Fisheries with Animal Genetic Resource department spearheading. Local government authorities can organize breeder farmers and facilitate formation of pilot pre-nuclei that will be used to demonstrate germplasm business under alliance. Later, upon successful demonstration of the business, the intervention can be scaled out using CBOGI as suggested by [19].

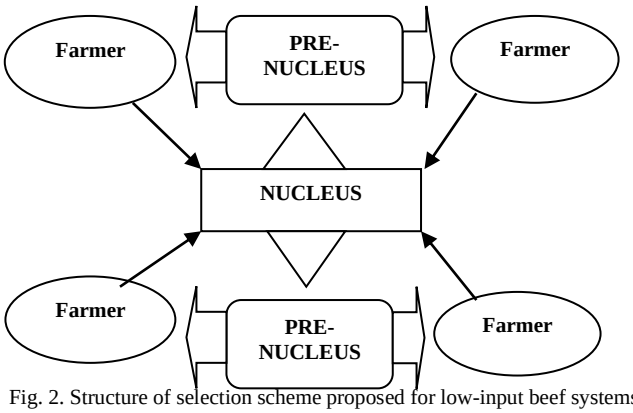

Fig. 2. Structure of selection scheme proposed for low-input beef systems of sub-Saharan Africa.

Key:

△ Represents flow of bulls from nucleus to pre-nucleus,

⇨ Represents flow of bulls from pre-nucleus to farmers,

→ Represents the flow of replacement cattle from farmers to the nucleus.

TABLE II: ROLES TO BE PLAYED BY THE ACTORS IN SELECTION SCHEMES PROPOSED FOR SUB-SAHARAN AFRICA

Actor	Key roles
Nucleus	-Produces bulls for supplying pre-nuclei -Sources replacement cattle from farmers
Pre-nuclei	-Receive bulls from nucleus and multiply them to get bulls for supplying farmers. -Spot potential cattle from farmers for nucleus replacement
Commercial farmers	- Buy improved bulls for breeding -Supply replacement animals to nucleus

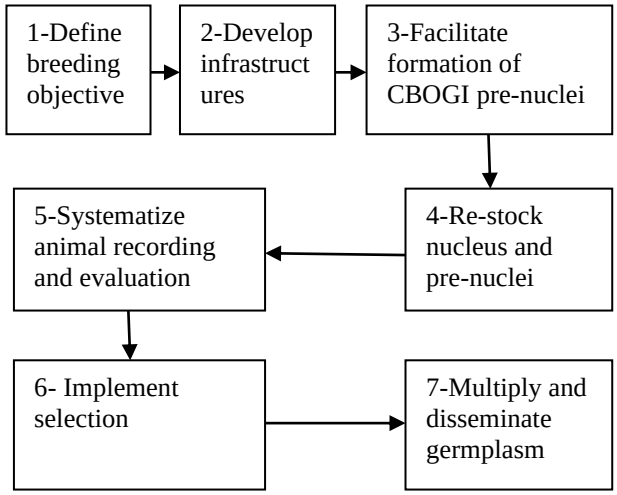

Fig. 3. Key steps towards operation of a selection scheme for TSZ cattle.

VI. CONCLUSIONS

Selection is a potential pathway for genetic improvement of indigenous cattle in sub-Saharan Africa and there are possibilities for successful exploitation with well laid foundation and implementation of realistic strategies. In the past the operation of selection schemes has been constrained more by unsustainable financing, low policy support and

weak technical foundation. Selection schemes involving dispersed farmer-based pre-nuclei, backstopped by institutional central open nuclei are considered appropriate to start with. For such schemes to work well they require well developed breeding objectives, organization, and empowerment of farmers to undertake community breeding using CBOGI, adoption of simpler alternatives to conventional breeding practices, promotion of inter-institutional collaborations in financing and implementing animal breeding, stronger coordination of animal breeding and advocacy for increased government financial support.

FUNDING

This study was financed by Tanzania Livestock Research Institute (TALIRI). The authors are very grateful to the financer.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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