Journal of Technological Sciences (JTS) Volume 1, Issue 2, 2023

Chinhoyi University of Technology
Journal of Technological Sciences
http://journals.cut.ac.zw/index.php/jts

Natural mating versus artificial insemination on reproductive performance of cattle in Zimbabwe's smallholder sector: A review

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Abstract

Effects of the natural mating and the artificial insemination breeding methods were reviewed. Breeding methods have significant impact on cattle reproductive performance in the smallholder sector livestock production sector. In Zimbabwe, over 80% of cattle population is found in the smallholder sector. Cattle production in smallholder sector is characterised by poor reproductive performance due to several reasons, among them the breeding method. A comprehensive systematic literature review search was conducted from August 2021 to July 2022 using search engines Google Scholar and EBSCO host to explore the impacts of different breeding methods used in smallholder sector of Zimbabwe. Fifty-seven full text articles met the inclusion criteria. Forty-one of the articles were research papers and sixteen were narrative reviews. The most common breeding method, the natural mating method, is easier for farmers but badly affected by communal system of grazing and limited number and diversity of bulls available. The alternative artificial insemination method is used by limited number of farmers due to lack of knowledge, skill and resources. Both methods of mating explored have their own advantages and disadvantages. The central problem to using the natural mating method is inbreeding. Inbreeding leads to a multitude of other problems all leading to poor reproductive performance. It was concluded that systematic revealing of problems and sequential chronicling of advantages can help farmers understand each of the two methods for better implementation and decision making on each method.

Keywords: Breeding, inbreeding, livestock, reproductivity, smallholder

Introduction

Livestock, particularly cattle play significant economic and social roles in the African society and economy (Mabhena, 2013; McDermott, Staal, Freeman, Herrero, & Van de Steeg, 2010). The biggest source of economic loss in cattle industry is reproductive failure which occurs when cows do not conceive during a defined breeding period (Perry, 2005). In Zimbabwe, Tavirimirwa et al. (2013) stated that large portion of beef cattle statistics (3.5 million) is mainly kept in rural communities of which these are mainly indigenous and crossbreeds. Smallholder farmers often uses natural mating systems and have a tendency to graze their cattle in mixed groups which encourages random mating and high incidences of inbreeding (Duguma & Janssens, 2021). This study seeks to explore the effects of different breeding methods on the success of cattle reproduction in the smallholder systems and attempt to find ways to improve the breeding methods in order to integrate modern developments in cattle breeding that can improve cattle reproduction potential.

Previous studies have demonstrated that lack of breeding plans among several other factors are contributing to low productivity in smallholder livestock farming systems (Mthi, Rust, & Morgenthal, 2016; Philipsson, Rege, & Okeyo Mwai, 2011). It is therefore necessary as highlighted by Nyamushamba, Mapiye, Tada, Halimani, and Muchenje (2017), that there is need to improve local breeds by developing appropriate and sustainable cattle breeding programmes in smallholder farming communities. Research done by Washaya et al. (2019) on reproduction efficiency in naturally serviced and artificially inseminated cows showed that AI had 77,6% conception rate while natural service had 56.79%. In South Africa it is estimated that more than 60% of the population depends on agriculture of which cattle production plays a very significant role (Braker & Udo, 2002; Greyling, 2012; Pareek et al., 2006).

Musemwa, Mushunje, Chimonyo, and Mapiye (2010) further noted that the contribution of cattle production to agricultural output in South Africa ranges between 25-30% per annum. It is estimated that 88% of households in Zimbabwean communal areas own cattle for various purposes (Musemwa et al., 2010). Cattle are pivotal in socio-cultural functions such as payment of lobola (Tavirimirwa et al., 2013), provision of milk, manure and also a source of fuel by some communities (Mutibvu, Maburutse, Mbiriri, & Kashangura, 2012), draught power, status symbol, as well as provision of protein in the form of meat.

In the study done by F. Marshall and Hildebrand (2002) they stated that, cattle plays a greater role in the livelihoods of people through socio-economic development and nutritional food security. The early African societies relied on cattle because they were shifting from one piece of land to another in search of grazing area for their cattle (Honeychurch & Makarewicz, 2016; F. Marshall & Hildebrand, 2002). Despite these well-known benefits of cattle, the current contribution to the national economy is dismal (Cletos Mapiye, Chikwanha, Chimonyo, & Dzama, 2019; Meissner, Scholtz, & Engelbrecht, 2013). In the smallholder sector, cattle farming of Southern Africa, communal areas demonstrates a high level of mortality (30%), a low reproductive rate, a low weaning percentage (C Mapiye, Chimonyo, & Dzama, 2009). It was established that beef cattle offtake rates were generally low in smallholder sector of Zimbabwe, currently at 3.3% compared to the national target of 15% (Musemwa et al., 2010; Tembachako, Ndlovu, & Mukomana, 2015).

A lot of new challenges are being faced in the livestock sector, despite the increase of the demand for livestock products to the extent that the chances of continuity of the intensive livestock sector is at high risk of extinction (McDermott et al., 2010). The beef cattle production in the smallholder sector in Zimbabwe was worsened by the fast track land reform programme of year 2000 which purported to empower the indigenous people that had been previously marginalised (Mujere & Dombo, 2011). However, despite the numerous benefits that came along with the land reform programme, a number of challenges have been witnessed, one of these being a decrease in the national beef herd (Moyo & Yeros, 2015). The fast track land reform did not support smallholder beef farmers particularly in the Matabeleland region of Zimbabwe (Mabhena, 2013).

People in Matabeleland region prefer extensive livestock rearing and hence continued occupation of small tracts of land for grazing is inappropriate. In the study done by (Mabhena, 2013, 2014) noted that in the Gwanda and Umzingwane districts, a lot of cattle were further lost in the communal areas due to dwindling pastures that was caused by the devastating drought of 2002. The Veterinary Department field services under the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development acknowledged that from 2000 to 2003 over 35 000 cattle had succumbed to draught due to lack of pastures and feeds (Mabhena, 2013). Stock theft and cattle diseases outbreak like anthrax, foot and mouth in the same period around 2002 further depleted the national cattle herd (Abebe, 2012). It is for this justification that in the time to come for livestock sector will be increasingly difficulty with the projected shortage of resources crucial for production especially grazing land and water under the change of climate (Escarcha, Lassa, & Zander, 2018; P. Thornton & Herrero, 2010).

Challenges facing the cattle industry

The major source of economic loss in cattle industry is reproductive failure which occurs when cows do not conceive during a specified breeding time (Perry, 2005). The quality and quantity of beef cattle continues to deteriorate particularly in the smallholder farming communities in Zimbabwe (Jera & Ajayi, 2008; Mabhena, 2013). Random mating, lack of trained staff and handling infrastructure, high costs and refrigeration of Artificial Insemination kits are some of the challenges in cattle production to smallholder farmers (Habanabakize, Ba, Corniaux, Cortbaoui, & Vasseur, 2022). The number of cattle in the livestock sector is always changing and not static, there are few studies on the impacts of livestock breeding systems done as compared to the studies of crops (P. K. Thornton, 2010). There is, therefore, need to explore these and attempt to find ways to improve beef cattle breeding methods in the smallholder farming sector for the attainment of Sustainable Development Goal number 2 (SDG 2) zero hunger on food security **(**Atukunda, Eide, Kardel, Iversen, & Westerberg, 2021)**.** The overall objective of the study was to seek ways to improve the beef breeding methods in smallholder farming communities of Zimbabwe. This overall objective would be supported by other smaller objectives, which were as follows: to explore beef cattle breeding methods, to identify strengths and weaknesses of the breeding methods, to identify useful traits in beef cattle and to find ways of improving the beef breeding methods in the smallholder livestock farming sector of Zimbabwe.

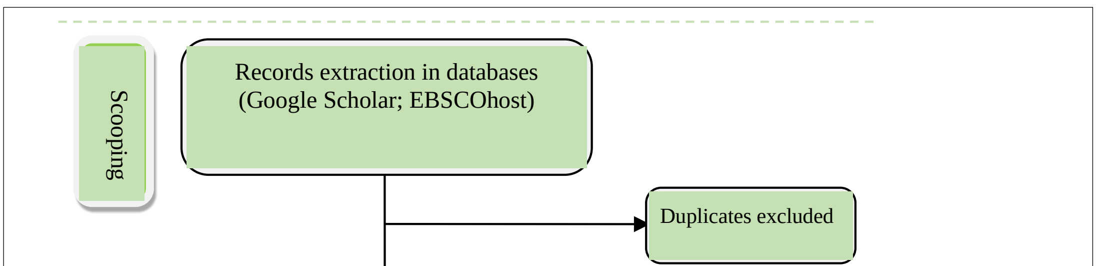
Materials and Methods

Procedure

The standard procedure on performing a systematic literature review (Okoli, 2015) was used. The search period was 2000 to 2022. The Google Scholar and EBSCOhost search engines were used to search for the articles mainly because of their ease of accessibility. The query was delineated to published journal articles that were found on-line. Grey or unwanted information like newspaper articles and unpublished papers related to cattle breeding methods were excluded from the study. The challenges associated with searching grey literature are that they are not evaluated by others working in the same field in the same way that published journal articles are so they should be considered necessary before making decisions to include them (Hoffecker, 2020).

For an article to be included in the study, the process was in agreement with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Moher et al., 2015). The main search words used for extracting the important required articles are, “Beef cattle” and “breeding methods.” In some instances snowballing from the reference sections of identified articles was done to look for more articles with information that is related to the study.

An outline of the search protocol for identification and selection of articles to be considered in this study is shown in Figure 1 below



Results and Discussion

Identification and selection of articles for inclusion

901 full text articles were tested for applicability to the study as indicated in Figure 2. Disaggregation or separation of the number of scooped articles by search phrases is shown in figure 2. The articles were extracted using the search term “Beef cattle” and “breeding methods”.

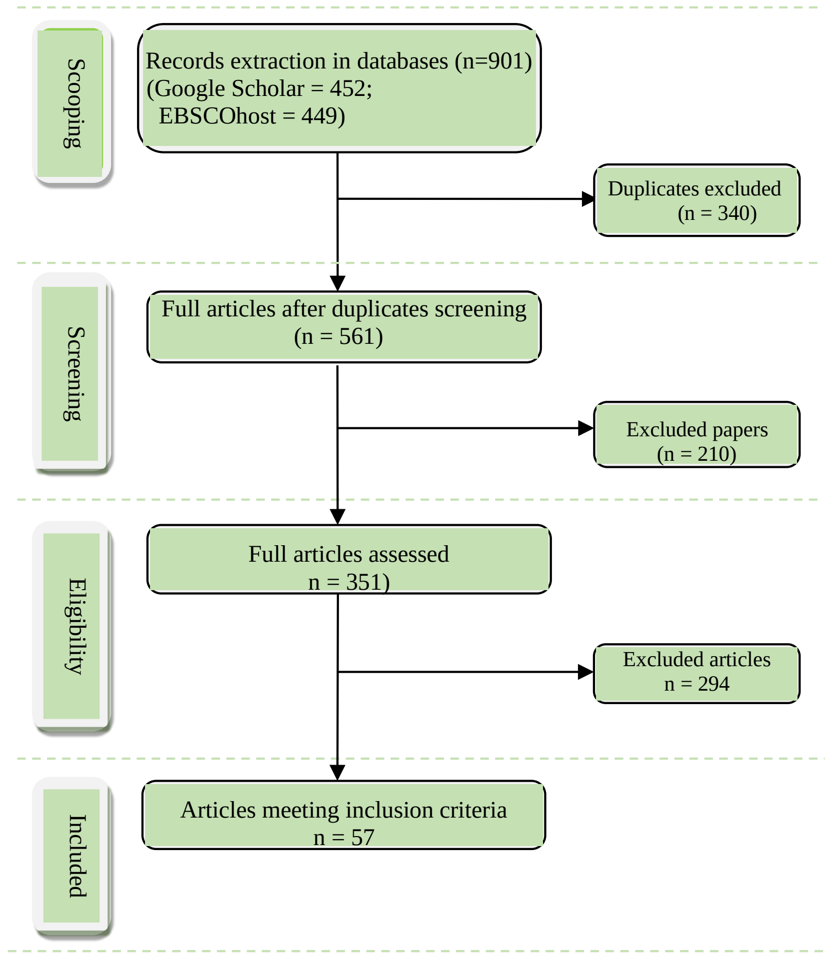


Figure 2 Summary of identification and selection of articles for the study

Fifty seven (57) full text journal articles satisfy the inclusion criteria. Forty-one of the articles were research papers and sixteen were narrative reviews. One breeding method that smallholder beef farmers can tap into is Artificial Insemination (AI).

Breeding methods

Breeding methods which going to be discussed are Artificial insemination, Natural service and multiple ovulation embryo transfer

1. Artificial Insemination (AI)

Artificial Insemination is the attentively introduction of sperms into a females' cervix or uterine cavity for the purpose of conceiving through in vivo fertilisation by means other than sexual intercourse (Nijamudeen, 2020). Artificial Insemination is enhanced by cross breeding (Lawrence et al., 2015). Sperms from say an Afrikander bull can be introduced to a Mashona or Tuli cow and to produce an offspring with the traits of both the Afrikander and Mashona. Such breeding technics gives positive results in genetic improvement in that animals with superior performance as a result of genes or alleles, are allowed to become parents and this results in raising the average level of performance over time (Miller, 2010). Furthermore, there is more hybrid vigor when the breeds being crossed are more genetically different (Getahun, Alemneh, Akeberegn, Getabalew, & Zewdie, 2019). Hybrid vigor can also be achieved when different families within the same breed are crossed, however the hybrid vigor is lower when two different breeds are crossed.

Cross breeding further results in the increase in the value of Heritability and Heterosis level in animals (Wakchaure et al., 2015). This is the easy by which a trait can be changed through selection which is determined by the trait's heritability level (Geber & Griffen, 2003). This is calculated as the percentage of the phenotypic differences that is due to the additive genetic difference and it is therefore important to note that the trait that have higher heritability value are easy to change because the animal's phenotype is more related to the additive genetic values (Geber & Griffen, 2003). Such breeding technics offers a lot of potential by increasing calf production and new composite breeds have been developed by crossing two or more breeds (K. Marshall, 2014). Indigenous breeds, even though they are adapted to local environments they are poor in meat production as compared to exotic breeds (Mpofu, 2002; Mwai, Hanotte, Kwon, & Cho, 2015). AI therefore makes it easy for farmers to cross indigenous and exotic breeds to produce animals that have both indigenous and exotic traits.

A composite breed means to crossbred cattle that result from the mating of crossbred bulls to crossbred females to form a new line of generation (Mishra et al., 2017) Examples of such composite breeds in cattle is the Brangus, which is an offspring of the Brahman and the Angus or Simbrah which is the result of mating a Simmental bull to Zebu cow (Paim et al., 2020). The other advantage is that cross breeding that is facilitated by AI is that diseases and parasites are controlled by eliminating bulls that might have been infected (Nyamushamba et al., 2017). In a study conducted by (Khainga, 2015) in Kenya it was reported that the main constraints to the use of AI is the unavailability of services and its associated costs in implementation as well as lack of breed varieties, failure of cows to conceive leading to repeat services and inadequate facilities and infrastructure (Khainga, 2015). Such challenges as the cost involved in AI can be circumvented by coming up with livestock marketing strategies that would be described later in this article.

2 Natural service or use of bulls

The other breeding method that is common in smallholder livestock cattle breeding communities is usage of the natural bull (C Mapiye, Chimonyo, Dzama, Raats, & Mapekula, 2009). In some instances, the natural bulls can also be used in cross breeding programmes. The bulls are selected for important relevant/significant traits but the shortcoming is that they are restricted on the number of cows or heifers they can service during the breeding period . (Diskin & Kenny, 2016; Ndebele et al., 2007). In many instances, uncontrolled breeding results in inbreeding which have a number of shortfalls such as small body frames, low growth rate and that the animals produced are prone to pests and diseases (Gwaza & Yahaya).
Extensive method of beef cattle production is mainly done in Southern African countries and dominated by indigenous beef cattle strains which are adaptable to the local environment (Nyamushamba et al., 2017; Tavirimirwa et al., 2013). The breeds include Nguni, Mashona, Tuli, Malawi Zebu, Angoni, Landim, Barotse, Twsana and Ankole. These breeds have traits ranging from drought tolerant, resistance to ticks and tick borne diseases, heat tolerance and resistance to trypanosomiasis (Mwai et al., 2015). Trypanosomiasis is a disease that is caused by tsetse flies that is prevalent particularly in Southern Africa. These traits need to be tapped into when coming with beef breeding programmes in smallholder communities. Indigenous cattle breeds found in Zimbabwe are Ngoni, Tuli and Mashona (Mpofu, 2002). Positive traits that are found in these breeds are; hardness highly fertile (Mpofu, 2002), high diseases tolerance, tolerant to high heat and low feed requirement (Moyo & Yeros, 2015) lean meat found from indigenous cattle contains less fat as compared to fatty meat from exotic breeds (Cletos et al., 2007). The Ngoni in particular have early sexual maturity, good foraging, good walking and mothering ability as well as high fertility (Nyamushamba et al., 2017).

However, when implementing breeding programmes, it should be noted that some indigenous breeds are also prone to some diseases such as trypanosomiasis for example the Zebu (*bos indicus)* (Shanahan, 2012). On the other hand, exotic breeds such as the Afrikander and the Brahman have traits such as high growth potential. Studies have demonstrated that indigenous breeds outperform exotic breeds when raised under communal rangelands conditions in terms of survival, meat and milk yield as well as high fertility traits (Mpofu, 2002). It is, therefore, recommended that in smallholder farming communities which are mostly found in communal lands with limited grazing area there is need to prioritise indigenous breeds to take advantage of the previously mentioned traits and cross them with the exotic breeds so as to tap on their high growth potential and other useful traits (Gwaze, Chimonyo, & Dzama, 2009).

Breeding that aims to succeed should collaborate the high productivity of exotic breeds with adaptive traits of indigenous breeds. In the smallholder beef farmers artificial insemination and management interventions could enhance productivity at the cost of improved genetic diversity and fertility (Vanvanhossou, Dossa, & König, 2021). In a study that was carried out at Matopos Research Institute, (Nyamushamba et al., 2017) reported that there was an improvement in the milk yield from a cross of Jersey and Ngoni as well as Jersey and Tuli. From these results, it can be inferred that crossing an exotic breed and indigenous breed can results in a breed which has positive traits from both parents.

3 Multiple Ovulation Embryo Transfer (MOET) Method

Embryo transfer is defined as a process of taking one or more embryos from the reproductive tract of a donor female and transferring them to one or more recipient females (Hasler, 2004). The cost of the embryo transfer process as a breeding method is beyond the reach of small holder farmers Selk (2002), it is one way that can be utilised for the quicker improvement in breeds in the view of high shortage of breeding bulls. Phillips and Jahnke (2016) outline the embryo transfer process starts by selection of the donor cow with good reproductive traits. The second stage in the process is superovulation of the donor cow, which is the release of multiple ova/egg at a single oestrus. After that, the insemination of the cow can be done several times during and after oestrus. The fourth stage involves the collection or flushing of embryos from the animals which are then ovulated and classified according to grades that are excellent, good, fair, poor, dead or degenerating. The embryos can be ovulated according to the stage of development without regard to quality. The stages are as follows: Stage 1: Unfertilised. Stage 2: 2 to 12 cell stage cell, Stage 3: Early morula, Stage 4: Morula, Stage 5: Early Blastocyst, Stage 6: Blastocyst, Stage 7: Expanded Blastocyst, Stage 8: Hatched Blastocyst, Stage 9: Expanded Hatched Blastocyst (Phillips & Jahnke, 2016). After the grading process selection and preparation of the recipient female cows that do not have problems in reproductive, that exhibit calving easy, and that have good mothering and milking abilities are selected as recipients (Hasler, 2004). If a cow is flashed every 90 days over a 12 months period and five pregnancies are obtained per collection, an average of 20 pregnancies per year could result. The final stage is the transfer of embryos into recipient cows by loading of embryos into a 0.25 ml insemination straw, this procedure is done under microscopic viewing with the aid of one millilitre syringe and it requires considerable practice, patience and dexterity (Phillips & Jahnke, 2016).

Just like other breeding method discussed earlier, the method has a number of advantages such as, the increased number of female sired from superior females, obtains offspring's from old or injured animals (Sheetal et al., 2015). Furthermore, it results in faster genetic progress and offsprings are obtained from old or injured animals incapable of breeding or calving naturally. On the commercial side farm income is increased through embryo sales. However, this breeding method has a number of challenges which includes costs involved which is beyond smallholder farmers and the skills needed in flushing the embryos (Phillips & Jahnke, 2016).

Smallholder farmers can benefit from such breeding technologies through government initiatives in strategic partnerships with development agencies. The government can came up with breeding programmes in smallholder cattle breeding communities. Such programmes can be implemented through institutions of higher learning such as universities and colleges as well as research institutions. Breeding bulls are produced in such institutions with the use of technologies such as AI and natural mating. Embryo transfers can be done with carefully selected cows from small holder farmers. By so doing, the government and development partners would go a long way in shouldering the cost involved in such breeding methods. Such strategic partnership goes a long way in improving the national herd thereby improving food security at both the household and national level

A table 1 showing strengths and weaknesses of breeding methods to be inserted below

Table 1**: Strengths and Weaknesses of beef cattle breeding methods**

Breeding method	**(+ve) Strengths and (-ve) Weaknesses**	**References**
Artificial Insemination enhanced by Cross Breeding	(+ve) Genetic improvement, animals with superior performance as a result of gene or alleles results in raising the average level of performance over time.	(Lawrence et al., 2015)
	(+ve) More hybrid vigor, when the breeds being crossed are more genetically different.	(Getahun et al., 2019)
	(+ve) Increase in the value of heritability of Heterosis level in animals	(Geber & Griffen, 2003)
	(+ve) Increase calf production and production of new composite breeds.	(K. Marshall, 2014; Paim et al., 2020)
	(+ve) Elimination of Diseases and Parasites	(Nyamushamba et al., 2017)
	(-ve) Unavailability of services and its associated costs in implementation and lack of breed varieties	(Khainga, 2015),
Use of the Natural bull	(+ve) Affordable to small holder farmers	(Archer, Barwick, & Graser, 2004)
	(-ve) Limited in the number of cows/heifers they can service during the breeding season	(Diskin & Kenny, 2016)
	(-ve) Uncontrolled breeding	(Diskin & Kenny, 2016)

	(-ve) Animals produced are prone to diseases and pests	(Gwaza & Yahaya)

To improve beef cattle breeding in smallholder communities, it is of paramount importance to train farmers on breeding management, especially on how to identify cow/heifer on heat and consequent planning for the breeding program. The service can be enhanced by employing a multifaceted approach to all the constraints for an enhanced breeding service. There is need to conserve indigenous breeds by making use of them, and to develop suitable breeding programs for smallholder beef production.

In order to maximise the benefits of services such as Artificial Insemination there is need to provide information to farmers to help them in making sound and confident decisions. The Government and the livestock sectors should be leaders in showing a clear and strong commitment to address the challenges and opportunities to ensure continuity and future of the livestock sector. This can be done through use of research stations and as well as agricultural institutions of higher learning like colleges and universities. It has been noted by (Odero-Waitituh, 2017) that inadequate facilities and infrastructure are hampering Artificial Insemination services.

Education 5.0 introduces the innovation technologies which enhances and motivates the farmers to upgrade their cattle productivity and production as well as provision of infrastructure (Gwaze et al., 2009) and increasing value to communal production of cattle. Facilities and structures for cattle breeding technologies can be set up at research institutions and open facilities in higher education institutions that can be used in the harvesting and storage of sperm that can be used by smallholder farmers at affordable costs. Institutions of higher learning and research have an advantage that they have expertise and knowledge of the processes such as sperm harvesting techniques, the genetic makeup of the harvested and stored sperm so they should educate smallholder farmers to commercialise livestock keeping.

Many African indigenous breeds are becoming endangered species now, and their different adaptive, economic traits can be lost forever if action is not done as a matter of urgency. These indigenous cattle genetic resources are in danger of extinction and disappear rapidly following uncontrolled crossbreeding and breed replacements with exotic breeds. Breeding improvement programs of African indigenous livestock remain too low while the demand of livestock products is continually increasing.

The end result is a continuous erosion and eradication of cattle diversity, including for adaptive traits, before these genetic resources are fully characterized. There is therefore a need for quick intervention to broadly characterize the local breeds of cattle, in order to objectively inform their utilization and conservation before they disappear (Mwai et al., 2015). To compensate for the relatively reduced production potential of indigenous cattle, crossbreeding of these cattle with exotic breeds, is commonly practiced, with minimal within breed selection program for the indigenous breeds.

It has been noted in a study done by (Khainga, 2015) that constraints of AI in beef cattle breeding in smallholder farmers are high costs involved through refrigeration of semen, the need for highly trained personnel and insemination tools or kits . One way to overcome these constraints is that livestock buying, selling and policy formulation in upcoming economies should be improved (Gwaze et al., 2009). Improving the marketing structures in smallholder farmers enable them to have a ready market which improves their disposable income. This cannot be done with individual farmers but rather they should be urged to make co-operatives and put their animal resources together.

The major challenge with the marketing of cattle products on smallholder farmers is dissemination of information on prices and market requirements (Coetzee, Montshwe, & Jooste, 2005). Such challenges can be dealt with through formation of cooperatives and farmers association whose role is information dissemination among other things. Marketing of cattle products can also improve by establishing more formal markets which would facilitates reopening of the export markets. In Zimbabwe companies like the Cold Storage Commission (CSC) should be made use of as these have lots of big infrastructures which are not being used (Mavedzenge et al., 2006). All this can be done through government intervention in supporting the smallholder beef producers. A successes story is that of South Africa in the Eastern Cape Province that was reported by (Cletos et al., 2007). In the smallholder areas, the marketing of the Nguni cattle and cattle products is fully supported by the government. There was serious stakeholder engagement to partner different players to build one roof industry which comprises of an abattoir, a meat processing area, a tannery, and a leather craft workshop (Eastern Cape Development Corporation). The project has embarked on various craft products from cattle skins which include hand-crafted 'organic' leather products to sell to the tourist market

(Musemwa et al., 2010). Hides have a ready market in exported Mercedes vehicles and the shoes industry (C Mapiye, Chimonyo, Dzama, et al., 2009). Such initiatives contribute positively to the to the farmers' disposable income that can be ploughed back to finance beef cattle breeding programmes.

Another initiative that governments could adopt is that of Meatco of Namibia (Shiimi, Taljaard, & Jordaan, 2012). The Namibian government supports communal livestock farmers via Meatco by providing credit facilities and source for new markets for communal livestock farmers under their a contract farming mechanism (Chinsembu, Negumbo, Likando, & Mbangu, 2014). Incentives to join the farmers associations include access to the export market of products such as deboned beef and tanned hides to the European and South African markets (Chinsembu et al., 2014). Smallholder livestock farmers should be urged to register their cattle with the organisations such as Livestock Identification Trust (LIT) to help them source new lucrative markets for their cattle. This should be good if there is some form of controlled and programmed breeding to help with pedigree identification (Tavirimirwa et al., 2013). This can be done through well-coordinated community development programmes in smallholder beef production communities by offering services like AI.

Conclusion and Recommendations

Smallholder beef farmers can make use of AI and reduce usage of the uncontrolled natural bull in their breeding programmes. The strengths and shortcomings of these methods have been highlighted. However more advanced breeding techniques such as Multiple Ovulation Embryo Transfer (MOET) and Genomic breeding can also be made use of in smallholder beef farmers to a lesser extent due to the inhibiting costs and the high technology that is involved. The successful breeding methods can be enhanced by cross breeding by mixing indigenous breeds, whose traits are resilience to pests and diseases, climate-related stress with exotic breeds which have higher growth rate to produce a breed with traits from both exotic and indigenous breeds. The paper recommends that there is need for support to farmers in terms of marketing so that they have disposable income to support breeding programmes. Support from research institutes and institutions of higher learning can also assist in coming up with innovative technologies and expertise that is necessary in conserving indigenous breeds as well as in the general improvement of beef cattle breeds in smallholder farmers. Improved genetics results in permanent and cumulative changes in beef cattle breeding.

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