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A Cost-Benefit Analysis of Usage of Sexed *in-vitro* Fertilization Embryo Transfer Technology in Kenya

Fridah G. Lawrence[a], Henry Mutembei [b*], Job Lagat[a], John Mburu[c], and Okeyo Mwai[d]

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[a]Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya.
[b]Department of Clinical Studies, University of Nairobi, Kenya.
[c]Department of Agricultural Economics, University of Nairobi, Kenya.
[d]Department of Animal Production, University of Nairobi, Kenya; International Livestock Research Institute, Kenya.

ABSTRACT

In Kenya, good quality heifers are in high demand but are generally unavailable and expensive. Innovative usage of sexed semen in an *in-vitro* embryo production (IVEP) system has a potential to help deliver appropriate cattle genotypes to farmers efficiently. Sexed *In-vitro* Fertilization Embryo Transfer (SIFET), which involves both IVEP and embryo transfer (ET), is a breeding technology which ensures a 90% success rate of achieving the desired sex of a calf. While SIFET technology is potentially beneficial, its costs and benefits have not been locally assessed. A cost benefit analysis was done to assess the economic feasibility of SIFET for commercial utilization in Kenya. Our results indicate that SIFET technology is a feasible option for potential investors. SIFET could benefit cattle farmers through availability of cattle of preferred sex (male calves for beef and female calves for dairy production) and better matching of genotype to farmers' production conditions. Such technologies can enhance regional trade in cattle breeding stock due to increased value and demand for Boran cows and heifers as donors and surrogates.

Key words: In Vitro Embryo Production, Cows, Cost analysis, Breeding, Kenya.

* Corresponding author E-mail:hmutembei@uonbi.ac.ke.

INTRODUCTION

Smallholder dairy farmers contribute 56% of the total milk production in Kenya (SDP Policy Paper, 2004). However these farmers face many constraints in their production. For example, heifer replacement programs take a long time and are rarely done properly resulting in high demand which is not satisfied by the low supply hence, prices are high. Further, there are disadvantageous sex ratios whereby there are too many males which are undesirable for dairy farming systems therefore high production costs are incurred. Also, farmers incur unrecoverable losses because the commercial relevance of many indigenous breeds is not optimized (Mutembei et al., 2008). Sexed *In-vitro* Fertilization Embryo Transfer (SIFET) technology can be applied to produce crossbred heifers which will not only match their environment but also address the issue of high cost of producing replacement heifers. Increasing the supply of heifers in low input systems will lower their prices. Improved conception rates, sustainable crossbreeding, and approximately 90% offspring of preferred sex are possible significant targets for reproductive technologies (Merton et al., 2003; Mutembei et al., 2015; Muasa et al., 2015).

The *in-vitro*-produced embryo is potentially more economical than embryos produced by superovulation because of the low cost associated with embryo production using abattoir-derived oocytes (FAO Report, 1991; Merton, 2014; Mutembei et al., 2015; Muraya et al., 2015). Other potential benefits include increasing efficient use of sexed semen, allowing pre-determination of sex of offspring and permitting pre-testing of actual fertility status of the bull (Mutembei et al., 2008; Merton et al., 2014; Mutembei et al., 2015). In Kenya, the usage and potential application of SIFET technologies have been tried and researched on (Mutembei et al., 2008, 2015; Muraya et al., 20 15). At the moment, SIFET project involves utilization of sexed semen from donor bulls with high potential for milk production but less adapted to low input systems to *in-vitro* fertilize oocytes from donor Boran cows with high reproductive capacity as well as better adaptation to harsh environment. The resultant embryos are then transferred to surrogate Boran cows.

The production strategy is expected to yield adapted F1 crossbred heifers with potential for high milk production. SIFET technology will result into sustainable utilization of indigenous breeds as oocyte donors and surrogate mothers as well as continuous production and access to adapted and productive F1 crossbred heifers (Hansen, 2006; Lawrence et al., 2015). Despite the promise in-vitro fertilization has, it is yet to be fully exploited in Kenya (Mutembei et al., 2008, 2015; Muraya et al., 2015; Lawrence et al., 2015). The cost of developing and delivering SIFET and its benefits under developing countries' conditions and especially in Africa is yet to be determined. Unlike in Latin America where SIFET has become one of the breeding methods in the cattle sub-sector, in Kenya this technology is still under research institutions. Information on costs and benefits of farmers and breeder organizations that would be involved in embryo production and transfer has not been investigated. Importantly, the implication of adopting this technology on livestock trade in Kenya has not been documented. Thus the objective of this paper is to analyze the costs and benefits of SIFET technology for breeder entrepreneurs using the case of pilot tests in Kenya.

MATERIALS AND METHODS

In the current study, cost allocation was done using activity based costing method. The activities were divided into; oocyte collection, embryo production in the laboratory and embryo delivery to farmers. Cost of oocyte collection was estimated based on transport cost incurred to collect oocytes from the abattoir within a radius of 20 km. This would ensure that the given six hours maximum time allowance between death of a cow and harvesting of oocytes from the cow is not exceeded. The cost of producing embryos was estimated using direct cost items identifiable from the laboratories. Interviews with lab technician and veterinary doctor were used in identification and estimation of the items and tasks in the production process. The cost of delivery was estimated using data from interviews with breeding service providers and the current market practices.

In estimating the cost of producing an embryo, direct materials, depreciation costs of equipment and labour costs is considered. Cost of non consumable assets and equipment such as refrigerators and microscopes is assigned as depreciation using depreciation rates according to standard costing method. Depreciation of equipment is done on reducing balance basis to determine the value of assets at the end of each year. Cost of labour is estimated using the current rates by the civil service of Kenya. Research, training and buildings' costs were not factored in; they were considered as sunk costs. It is assumed that at any one point, a batch of 25 embryos is produced and transferred. The monetary unit of valuation is Kenyan Shillings (Ksh). Items valued in terms of dollars were converted at an exchange rate of 100 Kshs = 1US $ (May, 2015). The cost of delivery incorporated cost of materials used for the actual embryo transfer, service charge and transport costs within a radius of 20 km as applied for AI transport costs. Total annual costs were considered as the cost of embryo production and delivery, plus equipment maintenance costs. The associated qualitative benefits were derived from focus group discussions with farmers.

The technology was explained to the farmers who were then asked to give perceived benefits of SIFET to their dairy farming. Further discussions were held with researchers. Interviews with breeding services providers and experts in animal breeding were also employed. Monetary benefits of the technology was estimated using farmer's willingness to pay for the technology extracted from baseline household surveys which was carried out in selected areas in the country. The technology was explained to farmers who were then asked to give the amount they were willing to pay for the technology. The given amount was treated as the price for the technology. Annual benefits were taken as the product of the price and quantity of embryo straws produced.

In the analysis three major parameters were considered; the net present value (NPV), the benefit cost ratio (BCR) and the internal rate of return (IRR) (Pearce 2006).

Net Present Value (NPV)

This is the total present value (PV) of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects. NPV is calculated using the function;

$$\mathbf{NPV} = \sum C_n / (1+r)^n \qquad 1$$

Where, n- Period; r - The discount rate; C_n - the net cash flow.

Table 1. Cost allocation of tasks in IVEP process.

Task	Cost per straw ($)	Contribution (%)
Oocyte collection	1.04	4
Production (SIFET)	8.02	32
Delivery	136	55
10% overhead allowance	2.27	9
Total	24.93	100

Table 2. Embryo delivery cost allocation.

Item	Cost ($)	Contribution (%)
Materials and chemicals	3.60	26
Labour	7.00	51
Transport	3.00	22
Total	13.60	100

Benefit-Cost Ratio (BCR)

The formula for calculating BCR was

$$BCR = \frac{PVB}{PVC} \quad 2$$

Where, PVB = present value of benefits defined as sum of discounted benefits PVC = present value of costs defined as sum of discounted costs.

Internal Rate of Return (IRR)

The internal rate of return on an investment or potential investment is the annualized effective compounded return rate that can be earned on the invested capital. It is the interest rate at which the costs of the investment lead to the benefits of the investment. Given the (period, cash flow) pairs (n, C_n) where n is a positive integer, the total number of periods N, and the net present value NPV, the internal rate of return is given by r in this formula;

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad 3$$

A sensitivity analysis was done to assess the effect of change in discount rate, costs and benefits on NPV, IRR, BCR and pay-off period.

RESULTS AND DISCUSSION

Cost-benefit analysis (CBA) refers to any type of structured method for evaluating decision options. It provides a means for systematically comparing the value of outcomes with the value of resources achieving the outcomes required. It measures the economic efficiency of the proposed technology or project. When there are many options to consider during a decision-making task, it is useful to evaluate the options with a common metric. CBA is widely accepted among business and governmental organisations. CBA provides is useful information for making decisions in both tangible and intangible monetary values for informed reasoning behind investments (Pearce, 2006).

Costs

From the in vitro embryo production laboratory, the total cost of equipment needed for production of embryos was estimated at $ 10,640. A maintenance cost of 10% per year was also allocated. From laboratory experiments the cost of one straw of embryo was estimated at $ 24.93. This incorporated oocyte collection, production and delivery costs. The cost of oocyte collection from abattoir contributed 4% of the total costs while that of production was 32% as shown in Table 1. The costs considered for delivery and their percentage costs to total delivery costs are shown in Table 2. An embryo can be transferred either fresh or frozen. Boran cows were used as recipients because they are known to be of highly fertile and good mothers even in harsh environmental conditions. Boran recipients are also considered to be low value animals in the dairy sector due to their low milk production, thus, the opportunity cost associated with them is low. In the analysis, it was assumed that frozen embryos will be transferred 7 days after the cow has shown signs of heat. This saves the cost of synchronizing the recipients.

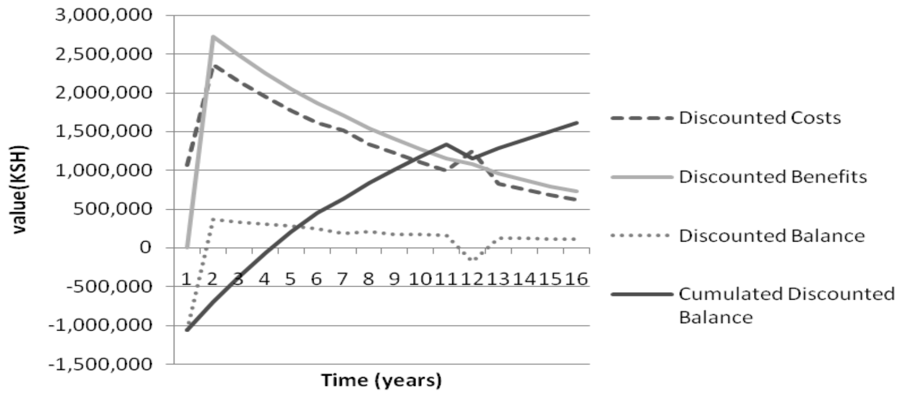

Figure 1. Discounted costs and benefits.

Table 3. Willingness to pay values and the basis of valuation.

Reasons given for minimum amount (2000)	Reasons given for maximum amount (6000)
Farmers economic status	Relative to cost of sexed semen
To allow everyone in the group to benefit	Cost of production and delivering
It is a new technology and farmers would like to try it first	Benefits for example, a faster way to get to preferred grade, breed and sex

Benefits

The benefits for the firm were assessed using price at which farmers were willing to purchase the technology, and the quantities. Minimum and maximum prices at which farmers were willing to purchase were assessed using the willingness to pay (WTP) methodology. During focus group discussions, farmers cited many perceived benefits of SIFET such as; (a) SIFET will help them to achieve preferred sex of calf and therefore save them the cost of raising undesired calves. (b) It is a shortcut to reaching high grade of the breed (pedigree) hence save on cost of pedigree female cow which is very expensive, (c) It will enable quicker breed improvement because the desired breed is produced faster and transferred quickly (shorter generation interval), (d) The technology will help them to save on cost of keeping a bull for natural service in the face of diminishing land holdings per household, and (e) It is a faster way to increase milk production since only female calves are born. Monetary benefits derived from average WTP as given in baseline household survey were estimated at $ 30 per straw of embryo (Lawrence et al., 2015). However, the amount that farmers were willing to pay was influenced by their economic status. For example, during focus group discussions, farmers considered their level of income when stating the amount they were willing to pay for an embryo transfer.

The reasons given are shown in Table 3. It is debatable how group membership affected the WTP. One focus group which comprised of members of a dairy group had both the highest and the lowest willingness to pay. The reasons given for the lowest value was that they considered the affordable amount that could benefit each member of a group. The highest value was given on basis of the high valuation of pedigree animals following previous group training. The willingness to pay amount is taken as the quantitative valuation of benefits, and therefore the price of a straw of embryo. Additional benefits arising from sales of assets at salvage values are injected at specific periods in the analysis. During the first four years of implementation, there are negative profits even though the benefits are positive as shown in Figure 1. However, this is immediately corrected after the fourth year during which positive profits are realised. Costs and benefits were discounted at a rate of 10% for 15 years. The slope of cumulated discounted balance curve depicts rate of change of profits over the years. Cumulated discounted profits increase at an increasing rate within the first 5years, followed by increase at a decreasing rate up to year 12 when it is less than zero. Figure 1 illustrates the trend of costs benefits and profits after discounting.

Parameters Considered in Investment Decision Making

NPV – This was calculated using Equation 1 above. In our analysis, the Net Present Value (NPV) was positive (Table 3). Following the general rule of acceptance if NPV is greater than zero, the project is acceptable.

BCR - Calculations were done using Equation 2. The

Table 4. Key indicators for investment decision making.

Sum in and of Discounted Costs (I)	**212,591.56**
Sum in $ of Discounted Benefits (II)	228,764.53
NPV (II) - (I)	16,172.98
IRR (%)	35.66
BCR	1.08
Pay-off period (year)	4

Table 5. Effect of variation of selected inputs on NPV, BCR, IRR and pay-off period.

Variation/variable	**Discount rate**			**Costs (10% change)**	
	10%	**15%**	**5%**	**Decrease**	**Increase**
NPV in $ (II) - (I)	16,172.98	10,440.32	25,088.13	35,948.78	-3,602.83
IRR (%)	35.66	35.66	35.66	61.42	1.26
BCR	1.08	1.06	1.09	1.19	0.98
Pay-off period (year)	4	4	3	2	NA

Benefit-Cost Ratio (BCR) is 1.50. This indicates that benefits are proportionately more than costs, therefore the project is acceptable.

IRR - An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return. Based on calculations using Equation 3, the IRR in our analysis is 98.31%.

Pay-off period - This is the amount of time taken to break even on an investment. Since this method is considering the time value of money and cash flows after the payback period, useful information on whether the investment is worthwhile is provided. The project's pay off period was 4 years (Table 4).

Sensitivity Analysis

Table 5 shows results of variation of discount rate, cost of embryo transfer and WTP on the parameters considered in previous discussion. The IRR was not affected by changes in discount rate. However, the payoff period reduced to 3 years at a discount rate of 5%. The IRR increases when cost of a straw of embryo is reduced by 10%. BCR and NPV are positive and acceptable regardless of the variations made on discount rate. However a 10% increase in production cost of a straw of embryo will lead to a negative NPV making the project unacceptable; the value of BCR (that is, 0.98) is below 1.0. The lowest NPV was recorded when discount rate is varied to 15%. In most variations the parameters remain positive and acceptable except when the cost of production is increased a lot.

CONCLUSION

The cost benefit analysis has shown that SIFET technology is economically feasible. Financial indicators are all acceptable even when a minimum commercial production level is considered. The benefits such as achievement of desired sex of animals and fast achievement of high grade of animals are all indicators of acceptability of the technology by the farmers. Laboratory outputs have indicated that IVEP and SIFET technologies are technically feasible in Kenya. The use of Boran heifers and cows as surrogates for embryos would lead to their increased demand, therefore providing a market for Boran cattle at improved prices as the law of supply and demand dictates. However, measures should be put in place to mitigate losses due to infrastructural inadequacies (Merton et al., 2006; Merton 2014). Delivery institutions should be established to reduce the cost of delivery which is the highest cost component. Policy should create an investment friendly environment to enable dissemination of the technology to small-scale farmers. Although this study was done considering small-scale dairy farmers, some of the data was for providing information. The CBA was basically done for commercial firms. Further analysis need to be done to establish SIFET viability at farm level.

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