

An Approach for Dairy Buffalo Development through Investment in Genetic Improvement

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Abstract: Dairy products are an essential source of animal protein, particularly for nutritional vulnerable groups and vegetarians in Asian countries. Therefore, the approach towards increasing the domestic supply of milk is to raise the buffalo milk yield via genetic improvement from the semen of the selected buffalo sire that possesses a high predicted milk difference. Data were collected from Artificial Insemination Centers in Egypt, as a case study, to apply a dynamic mathematical investment model for estimating the rate of return (IRR) to genetic investment. The effective variables in IRR, besides the economic variables, are the reproductive traits and feed efficiency. The estimated most probable level of IRR was feasible, i.e., 19.71%. A worse change in the reproductive efficiency variables, i.e., the aggregate of 10% increase in the number of conception services, age at the First Calving, and the service period, would decrease the IRR by 7.51%. A decrease in feed efficiency by 10% would decrease the IRR by 9%. A worse change by 10% in the feed costs, price of semen, and milk price would decrease IRR by 7%. To import buffalo sires' semen of high predicted milk difference at moderate prices till establishment, domestic genetic merit is required.

Keywords: Dairy buffalo, Feeds, Genetic improving, Investment model, Reproductive traits.

INTRODUCTION

Egypt has a comparative advantage in milk production from the domestic dairy buffalo, rather than red meat production [1]. Therefore, the feasible development plan is essential to give priority for increasing the domestic milk supply rather than red meat production from Egyptian buffalo, particularly that importing fresh milk and/or dairy products is highly expensive because they are very perishable food commodities [2]. The importance of increasing the domestic production of milk in Egypt via genetic improvement stems from the lack of sufficient resources for horizontal expansion in livestock population due to the limited feeds production, water, and agricultural land resources constraints [3]

Egypt has almost no natural rangeland, which creates issues in high competition between grain crops and green foods on limited irrigation water and agricultural land to satisfy the demand for human food and livestock feed, respectively [4]. The main livestock feed is the Egyptian clover (Berseem), which is a winter season crop (Oct-May) that competes with wheat on agricultural resources [5]. Cultivated berseem area determines the milking head numbers, the calf crop, and the milk supply [6]. Therefore, the increase in dairy heads beyond the carrying capacity goes as off-take for slaughter [7].

Due to before mentioned constraints, expansion in livestock dairy heads would not be economical to cover the increasing deficit between milk production and the effective demand [7]. Accordingly, the only possible approach for livestock development in Egypt is to fix the livestock size within the carrying capacity of the food availability allowance, focusing on the vertical expansion by increasing the milk yield per milking buffalo head [8], significantly. Such vertical expansion should be approached via genetic improvement of the domestic buffalo population using Artificial Insemination (AI) with the semen of selected buffalo sires [9]

The accumulation of costs and returns of genetic improvement over time and actualize the different strategies over different periods, should be expressed in comparable time units due to differential expression of improvement from a selection over time [10]. Discounting is the usual method of comparison for which revenue streams and future costs are transformed into existing values. Financial and economical are the two types of cost-benefit analysis [11]. The financial examination is the evaluation of a project's feasibility from the perception of agencies or individuals. The welfare of the nation at a core is considered for economic analysis. Financial analyses might be appropriate for Egypt as the breeding industry is often controlled privately [12].

In this regard, the study has designed and implemented a mathematical model to estimate the internal rate of return (IRR) along with the full productive life of the daughter of the dairy buffalo using

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the AI of the concerned sire's semen. The study estimated the most likely IRR at the average performance of the buffalo reproductive traits and the significant economic variables. After that, it estimated the impacts of unfavorable economic conditions, and less efficient reproductive traits, i.e., older age at first calving, more numbers of AI services required for conception, and a more extended service period leading to a longer calving interval, as well as the less feed efficiency.

To determine the return to investment of genetic improvement, the ordinary cash flow statement does not fit because livestock is a dynamic investment model of production, not an ordinary investment type. It is characterized by the depreciation of assets and treated via a systematic annual cash flow of benefits and costs. It needs a special financial mathematical model. The time horizon of such a model is determined by the inseminated dairy buffalo's production cycle and the five successive lactation seasons of its daughter. While the investment cost is determined by the semen dose price and the Number of conception services [13], the life cycle of such an investment is determined by the reproductive criteria.

The major reproductive criteria include age at first calving and the calving interval. As the gestation period is constant, the service period length determines the calving interval. On the other hand, the milk yield level and persistency period require adjustment for cow age and milking season order [14]. Feed efficiency is also an essential techno-economic variable that affects milk productivity and profitability as it represents the highest proportion of the operation costs of dairy cattle farms [15]. Most textbooks on feasibility studies of agricultural projects avoided such dynamic models [16-19]. Even the previous studies which applied assessment of the sire's predicted difference restricted the analysis for comparison among sires in terms of the net present value (NPV) of the first calving of the daughter because the authors were interested only in finding an index for sire's selection [20, 21].

MATERIALS AND METHODS

The use of artificial insemination technology (AI) in Egyptian agriculture is very limited, whether with the traditional or specialized herds, and there is a lack of reproductive or even productive records in most farms [22]. Therefore, the study sample was restricted to the data of the records of the specialized research centers, where artificial insemination records can be obtained. Therefore, it is a purposive non-probabilistic sample.

As the number of artificial insemination centers is very limited in Egypt, the sample included the records of one of the largest Buffalo Research Stations in the Gharbia Governorate, which is in the middle of the Nile Delta region. It is managed by the Ministry of Agriculture and Land Reclamation.

Such a purposive sample provided various privileges. Firstly, the Centre's management understood the nature and importance of the study and thus, facilitated access to the required data. Secondly, the availability of records was for two herds at the station, one set was a flock of naturally inseminated dairy buffaloes with the semen of unselected bull (18 heads), and the second a herd of daughters of buffalo dams artificially inseminated by the semen of selected buffalo sires (15 heads). The records of the first herd (18 heads) of dairy buffaloes were used to get the dairy buffalo's average productive and reproductive performance variables without genetic improvement. The second herd included the daughters (15 heads) of dams under the AI program of the improved sire's semen. The second herd records were used to get the average milk yield of the genetically improved daughters.

The average of productive and reproductive traits estimated from the records of the genetically unimproved sample is presented in Table 1. The milk yields over successive milk seasons of the genetically unimproved herd were used to calculate the Mature Equivalent Factor (MEF), as shown in Table 2. The MEF index was used to adjust the milk yield resulting from the estimated Predicted Milk Difference (PMD) to represent the improved milk yield of daughters over five successive seasons [23]. The second sample data were used to estimate the average milk yield per season of the daughters of the dairy buffalo dams inseminated artificially by the semen of selected buffalo sires raised in the artificial insemination center (Table 2). This sample was also used to estimate the PMD as the criteria of probable improvement in the milk yield of the Egyptian buffalo population in Egypt. When determining PMD, the population average of the daughters' milk yield was compared with the average milk yield of the genetically unimproved dairy buffalo herd.

The classical investment analysis model calculates the discounted net benefit derived from the cash flow as a stream of both annual inflows (costs) and outflows (benefits). However, it does not fit the purpose of the

genetic investment analysis. The livestock investment model was affected by the changes in the reproductive cycle. Such a cycle comprises a set of variables that were measured in days and months and not on a full year base. These reproductive performance traits were mainly the age at the 1st calving, the service period (the period between calving and the successive conception of the dam), the calving interval (the sum of the gestation period and service period), and the Number of services required for conception and the mortality rate. Therefore, the IRR estimation (the discount rate that maximizes the return to investment) would be affected by nonsystematic periods measured in months. In addition, the outflows (revenues or benefits) are generated from the probable increase in milk yield of the daughters of the inseminated dam from the concerned breeding sire.

The sire is supposed to transfer what is called the "Predicted Selection Difference" of the milk of the semen, i.e., "PMD". It represents the potential quantity of milk, which is added to the average yield of his daughters. The investment costs in this study were the price of the units of AI from a certain sire's semen. The level of such a price was associated with the level of PMD. The feed costs were the bulk of the operating costs [24]. The feed cost was mainly a function of the feed conversion rate, which, in turn, was the most vital productive trait that affects the return to investment [25]. The incremental net benefit's model considered only the feed costs as the main variable costs' item, which directly affects the changes in milk yield.

The Model's Assumptions

- (1) The investment period expanded to 10 years, to allow for the genetic investment to give its full potentiality over five successive milking seasons of the daughter of the served dairy buffalo by the selected sire.
- (2) The average age at the first calving estimated from the field survey data.
- (3) As a conservative evaluation, it was assumed that the first replacement heifer of the offspring comes from the second calving of the served dairy buffalo.
- (4) To avoid the exact date of the conception, when the cost of the inseminated semen was allocated, it was assumed to be at the onset of each calving interval.
- (5) The gross margin above the feed costs introduced in the model was a ratio from the total income (incremental income above feed costs).
- (6) As the model focuses on genetic improvement of the milk yield, thereby the income generated from the calves' crop is neglected.
- (7) The minimum nominal interest rate was the financial average discount rate in the financial market of Egypt in 2017.
- (8) Such an interest rate was used as a standard to compare it with the rate of investment generated from the genetic improvement of the dairy buffalo. Therefore, the estimated IRR is considered feasible if it passes the standard interest rate and is above the inflation rate in milk price.
- (9) The base period is the time of introducing the first semen service.
- (10) The discounted net present value should be calculated on a monthly base rather than a yearly basis.

Analytical Procedures

The analytical procedure was presented in a comprehensive approach via six sections: estimating PMD, the model's hypothesis, the model's equations, the definition of the model's variables, and the model's assumptions.

Estimation of the Predicted Milk Difference

The PMD was the probable increase in milk yield above the herd average transmitted from the semen of selected sire via the artificially inseminated dairy buffalo to its daughters. The PMD in this study was estimated from the model of Equation 1:

$$PMD = (MY_d - MY_h) * (h^2) \quad (1)$$

where:

PMD = Predicted Milk Difference supposed to be transmitted to the daughter via the inseminated dam from the selected buffalo sire,

MY_d = the average milk yield per daughter per season,

MY_h = the average milk yield per season of the target buffalo herd, and

h^2 = heritability coefficient of buffalo milk [26]

It should be mentioned that the mathematical model was presented in this study for assessing the feasibility of the AI program for genetic improvement of the milk yield of the domestic dairy buffalo. However, it was recommended for other dairy livestock types (cattle, sheep, or goats) by introducing the correspondent technical coefficients of each type. In addition, it is valid not only for assessment of the genetic assessment of milk yield, but it is also applicable for other traits of milk quality, particularly milk fat and milk protein contents, which could be added to the model when such quality criteria have significant impacts on milk demand and price. If such traits were added, weights should be associated with each trait generated income to reflect the national strategy towards investment in genetic improvement for milk production.

The Mathematical Model's Equations

The model composed by the authors simulated the classical investment statement or the cash flow statement of the projects' appraisal [19], but it was adapted to fit the study's objectives. Therefore, it comprised of 17 equations, as follows:

$$NPV = nP_1 - nP_2(1+i)^{-a} - nP_3(1+i)^{-b} - I_1(1+i)^{-c} + I_2(1+i)^{-d} + I_3(1+i)^{-e} + I_4(1+i)^{-f} + I_5(1+i)^{-g} \quad (2)$$

$$I = r_c - r_p \quad (3)$$

where

r_c = interest rate in the Egyptian financial market

r_p = inflation rate of producer milk price

$$\Sigma NPV = \text{Zero} \sim i = IRR \quad (4)$$

where

NPV = Net present value

$$n = 100 / ACR \quad (5)$$

where

n = Average number of semen units/calving interval, for "k" intervals, where $k = 1, 2, 3, 4, 5$

$$ACR = CR(1 - \% \frac{MR}{100}) \quad (6)$$

where

ACR = Adjusted conception rate (%)

CR = Conception rate from the 1st service (%)

MR = Mortality rate of dairy buffalo (%)

$$I_k = M_k(I - R) \quad (7)$$

where

I_k = Incremental milk income above feed costs at calving interval k, in (EGP)

$$M_k = P_m \left(\frac{PMD}{MEF_k} \right) * (MD) \quad (8)$$

where

M_k = Incremental milk income at calving interval k, in (EGP).

PMD = predicted selection difference for daily milk yield (Kg) for the concerned breeding sire.

P_m = average price/ 1-kg of milk at the base year (EGP)

$$R = (M_k - FC) / M_k \quad (9)$$

where

M_k = Incremental milk income at calving interval k, in (EGP).

R = proportion of feed costs in gross milk income from a daughter of the breeding sire.

$$CI = GP + SP \quad (10)$$

where

SP = service period

GP = gestation period

$$a = AGC \quad (11)$$

$$b = a + CI \quad (12)$$

$$c = b + AGC + 0.5LP \quad (13)$$

$$d = c + CI \quad (14)$$

$$e = d + CI \quad (15)$$

$$f = c + CI \quad (16)$$

$$g = f + CI \quad (17)$$

Table 1: Estimated Averages of Major Traits of the Inseminated Dairy Buffalo Herd

Productive and Reproductive Traits	Average
Average Number of Services for Conception	2.00
Average Adjusted Conception Rate from 1 st service (%)	50%
Age at 1st calving (month)	32.50
Average daily milk yield (Kg)	7.6
Average lactation period per season (day)	230
Average Milk Yield per season (Kg)	1781.5
Average Calving Interval (Month)	450
Average Service period	135
Average feed costs per Kg milk (EGP)	3.15
Average Proportion of milk Cost in Total Revenue (%)	69%

Source: Compiled and calculated per 1-dairy buffalo from the inseminated buffalo herd in the AI Center; except the last row, which comes from the records of the genetically improved daughters *EGP = (Egyptian pound); 1-US\$ = 17.60 EGP in 2017.

Where:

AGC = age at first calving

CI = calving interval

RESULTS AND DISCUSSION

The average reproductive performances of the domestic dairy buffalo were presented in Table 1. The average age at first calving was around 32.5 months; the service period was 135 days, and the calving interval reached 450 days. The required Number of services for conception was around 2.0. However, the effects of the order of lactation seasons of the dairy buffalo on milk production have been taken into consideration via correction for the MEM of dairy buffalo, as shown in Table 2. Accordingly, the PMD in the k lactation season was adjusted for the predicted milk yield per season over five successive seasons using the corresponding MEM index. The mature calving season is the 3rd season, where the PMD would

Table 2: Estimation of the Mature Equivalent Index of Milk Yield/ Season (MEM)

Lactation Season	Mature Equivalent Factor
1st Lactation	1.4
2nd Lactation	1.2
3rd Lactation	1.
4th lactation	1.1
5th lactation	1.1
Average milk/season/ dairy dam (Kg)	1781.5

Source: Compiled and calculated from.

(1) Van Tassell, *et al.*, 1995.

(2) The inseminated buffalo herd in the AI Center.

reach its full performance, i.e., MEM equals one, and then there would be a slow decrease in the milk yield of the daughter in the 4th and the 5th season.

Therefore, the increase in the daughter milk yield would reach its full potential incremental increase (PMD =425 kg milk/day) as derived from Equation 1 in the 3rd season. Such an amount multiplied by the Number of milking days would be fully added to the average milk yield per cow of the herd, and a lesser amount of milk would be added to the other seasons.

Internal Rate of Return

IRR is the discount rate, which made the sum of the NPV equal to zero at the most probable levels of the performance profile. As shown in Table 3, IRR was estimated as 19.71%. It is much higher than both the annual inflation rate in milk price (10.5%), and the average discount rate in the financial market in 2017 was 16.0% [27] Therefore, the genetic improvement in domestic dairy buffalo was significantly feasible. The Number of domestic milking buffaloes in Egypt was around 1.769 million heads in 2015 [28]. Therefore, an expected additional increase in domestic milk supply per year due to genetic investment would be around 751,981 tons.

Such an incremental quantity would reach around 13.5% of the existing milk production of Egypt, which reached 5.551 million tons in the same year. However, such a predicted increase in milk production covers around 64.4% of imported fresh dairy products, estimated as milk equivalent [28]. If buffalo milk were estimated as 4% fat milk equivalent, rather than 7.8%, using Jean's equation [29], the expected increase in milk yield would represent about 23% of total milk

Table 3: Average Economic and Reproductive Variables of the Investment Model

The Model's Variables	Symbols	Average
Economic Variables		
Farm Gate Price of Milk (EGP)	P_m	5.00
Average discount rate in the financial market in 2017 (%)	r_c	16%
Annual Inflation rate of producer Price of milk (%)	r_f	10.50%
Average Monthly discount rate (%)		1.33%
Semen Price per unit (EGP)	P_s	50
Proportion of milk Cost in Total Revenue (%)	R	69%
Technical Variables		
Expected Selection Difference of the semen (Kg)*	PDM	425.00
Average Number of services for conception	ACR	2.00
Adjusted Conception rate from 1 st Service (%)	CR	50.00%
Mortality rate of Dairy Cows	MR	1.2%
Age at the First Calving	AGC	32.5
Calving Interval	CI	450
Service Period	SP	135

Source: compiled from Table 1; *Estimated from (Equation 1) using data of Table 1.

production and 109% of imported milk equivalent of dairy products.

Sensitivity Analysis of the IRR towards Undesirable Conditions

The predicted changes in the IRR due to probable deterioration in reproductive and productive performances of the domestic buffalo were estimated as presented in Table 4. A 10% increase in the Number of services for conception, age at first calving and service period would aggregately decrease the IRR by 7.5% to be around 12.2%, i.e., the IRR on the genetic investment would not be feasible as it became less

than the interest rate on livestock loans. An increase in feed costs by 10% would drop the IRR by 9% to reach about 11%, which almost covers the annual inflation in milk prices, without any positive net benefit to entrepreneurs. Such an increase in feed costs could be due to either an increase in feed prices or a decrease in feed efficiency.

Unfavorable changes in the economic variables, i.e., a 10% increase in semen dose price and milk price, would be around 7%. It is of less drastic negative impact on IRR than a similar change in reproductive traits or feeds efficiency, i.e., to reach around 13%.

Table 4: Estimation of Most Probable IRR and Sensitivity Analysis

Model's Critical Variables	Expected Change	Estimated IRR	Change in IRR
Most Probable IRR	No change	19.71%	0.00%
Milk Price	10% less	15.98%	-3.73%
Semen Unit Price	10% more	16.67%	-3.05%
All Economic Variables		12.67%	-6.98%
Number of services for Conception	10% more	16.26%	-3.38%
Age at the First Calving	10% more	16.15%	-3.50%
Service Period	10% more	19.09%	-0.62%
All Reproductive Traits	10% more	10.85%	7.50%
Feed Efficiency	10% more	14.06%	-5.65%

Source: Calculated from the Investment Model using Tables 1 and 2.

Therefore, a national research work supported by an effective extension program should be implemented to improve the reproductive traits and feed efficiency of the buffalo population.

Policy Implications

A 10% increase in the feed conversion rate decreases the return to investment of the genetic improvement of dairy buffalo by 9%. A 10% increase in the Number of services for conception, service period and age at first calving would also decrease such a return to investment by another 7.5%. Therefore, to assure a feasible return to investment in such a program, some supporting policies are required.

Among those policies is a training program for the inseminators and dairy buffalo holders on precise heat detection on time and proper application of AI. Such a program would help in decreasing the Number of services required for conception and consequently, the calving interval, which raises the return to investment. A supporting program should be associated with it. Such program objectives are a sufficient communication system for calling the inseminators on time, and the availability of sufficient transportation means in the villages, such as motorcycles.

A proper feeding system for replacement heifers would enable them to reach an appropriate weight earlier for breeding at a younger age for first calving. A credit line of soft loans should be provided to veterinary and agriculture college graduates to establish AI stations, and large investors to establish AI centers that produce liquid nitrogen and prepare the semen dose containers.

The main method of genetic improvement of buffaloes in Egypt was the importation of buffalo sire's semen. These were the tactics of choice due to the inadequate development of local breeding infrastructure. However, local progeny might be an economically suitable option for Egypt and can be an effective alternative with restricted foreign currency. Therefore, an economic assessment of a series of alternatives is required with a range of strategies and methods that might be beneficial to develop effective breeding policies for buffaloes, not only in Egypt but also in Asian countries.

The dairy breeding industry will consequently benefit from the major investment in genetic improvement research that is presently underway.

Genetic improvement programs would be embraced by large dairy producers and will consequently provide a sound investment market. The unemployment would be reduced due to the consolidation of the artificial insemination network and other dairy industries, where, currently, the investments in the dairy sector Egypt, by private and public institutions are inappropriate.

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