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Abstract

Dairy products are 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. Field sample survey data were used 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 10% decrease in the reproductive efficiency variables 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 a domestic genetic merit is required..

Keywords: Dairy buffalo, Feed, 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 (Soliman and Mashhour, 2004). 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 given that importing fresh milk and/or dairy products is highly expensive because they are very unpreserved food commodities (Soliman & Bassiony, 2012). 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 (Elmowafy, 2015).

Egypt has almost no natural range land, which create 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 (Safwat, et al. 2015). The main food is the Egyptian clover (Berseem), which is a winter season crop (Oct – May) that competes with wheat on agricultural resources (Aboelgoud, Mersal & Haggag, 2015). Cultivated berseem area determines the milking head numbers, the calf-crop and the milk supply (Radwan, 2016). Therefore, the increase in dairy heads beyond the carrying capacity goes as off-take for slaughter (Soliman, 2007).

Due to beforementioned constraints, expansion in livestock dairy heads would not be economical to cover the increasing deficit between the milk production and the effective demand (Soliman, 2008). 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 significantly the milk yield per milking buffalo head (Soliman, 2007). Such vertical expansion should be approached via genetic improvement of the domestic buffalo population using Artificial Insemination (AI) with semen of selected buffalo sires (Warriach et al., 2015).

The accumulation of costs and returns of genetic improvement over time and are actualized for the different strategies over different periods. Results should be expressed in comparable time units due to differential expression of improvement from selection over time (De Vries, 2017). Discounting is the usual method of comparison for which revenue streams and future costs are transformed to existing values. Financial and economic are the two types of cost-benefit analysis (Kadarmideen et al., 2018). 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 (Pangmao, Thomson, & Khatkar, 2017). In this regard, this study has designed and implemented a mathematical model to estimate the internal rate of return (IRR) along the full productive life of the daughter of the inseminated dairy buffalo using the AI of the concerned selected buffalo sire's semen. Therefore, the study estimated the likely estimates of IRR at the average performance of the buffalo population reproductive traits and the major economic variables. Thereafter, it reiterated the model to estimate the impacts of hypothesized scenarios of unfavorable economic conditions, and also tested for less efficient reproductive traits, i.e. older age at first calving, more numbers of AI services required for conception, and a longer service period leading to a longer calving interval.

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 characterized by 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 production cycle of the inseminated dairy buffalo and the five successive lactation seasons of its daughter. While the investment cost is determined by the semen dose price and the number of services for conception (Soliman, 1985), 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 (Mashhour, 1995). Feed efficiency is also an important techno-economic variable that affects milk productivity and profitability as it represents the highest proportion of the operation costs of dairy cattle farms (Brown, 1979). Most textbooks on feasibility studies of agricultural projects avoided such dynamic models (Lumby, 1991; Gittenger, 1982; Barnard, and Nix, 1979; Brown, 1979). 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 (Blake, 1989; McMahon, 1985).

Materials

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 (Ibrahim, 2012). Therefore, the sample of the study 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 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 for two herds at the station, one for 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 average productive and reproductive performance variables of the dairy buffalo 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 both 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 for adjustment of the milk yield resulting from the estimated Predicted Milk Difference (PMD) to represent the improved milk yield of daughters over five successive seasons, (Van Tassell, et al, 1995). 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. To homogenize the management; when estimating PMD, the population average of the milk yield of the daughters was compared with the average milk yield of the genetically unimproved dairy buffalo herd.

Methods

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 (Pryce, 2001; Mara, 2005). 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. Thereof, the incremental net benefit's model, considered only, the feed costs, as the main variable costs' item which affects, directly, 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 as a ratio to 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 - 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; and

(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, which are: 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 that would be 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:

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

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 (Negm, et al, 2005)

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 was valid not only for assessment of the genetic assessment of milk yield, but it was 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 the generated income of each trait to reflect the national strategy towards investment in genetic improvement for milk production.

The Mathematical Model's Equations

The model comprises 18 equations, where some are structural equations and others are based on simple definition:

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

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

where

r_c = interest rate in the Egyptian financial market

r_p = inflation rate of producer milk price

$$\sum NPV = Zero \sim i = IRR \quad (4)$$

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

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

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

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

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

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

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

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

Where: CI = calving interval

Results and Discussion

The average reproductive performances of the domestic dairy buffalo were presented in **Error! Reference source not found.**. 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 **Error! Reference source not found.**. 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 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.

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 1st 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 Carving 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

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

Economic 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%) (CAPMAS, 2017), and the average discount rate in the financial market in 2017 was 16.0% (Central Bank of Egypt, 2017). 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 2014 (FAOSTAT, 2015). 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 was around. 5.551 million tons in the same year. However, such a predicted increase in milk production covers around 64.4% of imported fresh milk equivalent to dairy products (FAO.Org/FAOSTAT, 2017). If buffalo milk was adjusted for milk equivalent to 4% fat, rather than 7.8%, using Jean's equation (Soliman and Abdul Zaher, 1984), the expected increase in milk yield would represent about 23% of total milk production and 109% of imported milk equivalent of dairy products.

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 1st 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

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 entrepreneur. 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. semen dose price and milk price, would be around 7%. It is of less drastic negative impact on IRR than either reproductive traits or feed efficiency, i.e. to reach around 13%. 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.

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%	0.0%
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

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 CI, 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 to 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 semen for sires of replacements. These were the tactics of choice due to the inadequate development of local breeding infrastructure. In addition, local progeny might be an economically suitable option for Egypt and can be the effective alternative with restricted foreign currency. An economic assessment of a series of alternatives is provided by the parameters, range of strategies and methods that might be beneficial to develop effective breeding policies for buffaloes in Egypt and other Middle Eastern countries. The dairy breeding industry will consequently benefit from the major investment in human genomic research that is presently underway. Genetic improvement programs are embraced by dairy producers and will consequently provide venture capitalists a sound market for human genome research. The number of employees has been reduced by consolidation throughout AI and other dairy industries in dairy cattle breeding. In dairy breeding research, current investments in the Egypt by private and public sources are inappropriate for nurturing that vital group as compared to a minimal level.

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