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Modeling of Automatic Milking Systems in Animal Production Farms

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ABSTRACT

The aim of the present study was to design a mathematical model that can be used when deciding to choose a milking parlor. The proposed model has been tested in the conditions of agricultural production in Egypt and can be easily updated and adapted to different conditions. The mathematical model was basically validated with some results of measurements on three farms of different sizes for milking parlors and could be easily adapted to changing conditions. The results of the model showed that in case of a farm that contains 250 cows, the number of hours needed for milking per day is 12 hours, and the design of the milking parlor (2x8). In case of a farm that contains 500 cows, the number of hours required for milking per day is 15 hours, and the milking parlor design is (2x14). While, in case of a farm that contains 1000 cows, the number of hours required for milking per day is 18 hours, and the design of the milking parlor is (2x22). The results also showed that by increasing the capacity of the dairy farm it was possible to reduce the final annual costs of milking costs, whereby if the difference between a farm containing 250 cows and 1,000 cows was compared, it was observed that the final annual costs of milking per cow were reduced by 22 %. From the application of the model, it was found that the milking parlor could be improved, with reducing the total annual final costs of milking per cow by 30 %.

Keywords: Modeling, Dairy farm, Parlor optimization, Automatic milking system, costs.

INTRODUCTION

The milking cycle is important on dairy farms. Milking represents about 40 % of the daily labor on the dairy farm. There are many problems which influence choosing and proper use of a milking parlor. Some of them should be solved in advance during preparation and design of a dairy farms. Livestock production in countries with intensive agriculture is currently undergoing big and rapid changes. Capacity of farms are therefore expanding and increasing the average annual milk production per cow. This leads to the modernization of the milking equipment. A similar process of enlargement and modernization of dairy farms can be expected in many countries, using the modeling (Gaworski and Leola, 2014; Gaworski and Priekulis, 2014). There are available solutions offered by manufacturers of either milking parlors (MP), or automated milking systems (AMS), equipped with milking robots. Some papers and academic journals present research findings and recommendations based on AMS issues, usually including comparisons of AMS and milking parlors, details related to performance issues and economic analysis in some journals (Maltz *et al*., 2003; Priekulis and Laurs, 2012). There are numerous practical recommendations in the literature, but typically no subeconomic data are included which leads to specific numerical results, characterizing the overall result of milking parlor solutions. Some publications (Dolezal *et al*., 2000; Chiumenti, 2004) present models focused on choosing milking parlors, but not in a complete universal approach which could be adapted everywhere. Similar calculations are provided in rotary milking parlors, completed with many significant economic results. (Ozolins *et al*., 2012). Currently, there are a variety of mathematical models and computational programs, which can help to optimize the solution of various functional dependencies. Suitable requirements for the decision-making process must always be sought. The results of research and basic equations used for calculation of several parameters of milking parlors are presented in [Gaworski and Priekulis, 2104]. Kic (2015a, 2015b) presents some results of optimization and calculation based on a mathematical model that focuses on the conditions of dairy farms and milking production. It is very important to find the correct criteria to choose the optimal type of milking parlor in line with the overall farm definition and to fulfill all operational requirements under suitable economic conditions such as final specific direct costs of milking parlor, the specific labor costs per cow and year, the milking equipment, and the specific costs of consumed supplies (Sada *et al*., 2016). There are many problems which affect the milking parlor's selection and proper use. It is very important to find the correct parameters that would allow the selection of the optimal type of milking parlor, which would conform to the overall farm definition and satisfy all operational requirements under suitable economic conditions. The milking time and the final specific direct costs are the key parameters which allow the dairy farm to evaluate and select an appropriate milking parlor. The calculation for the verification of this method and these criteria shows that by optimizing of the milking parlor and increasing the capacity of the farm it is possible to reduce the final costs of milking per cow/year by 30 or 40 % (Kic, 2015). State the ability of automatic milking systems (AMS) under operating conditions and decide the maximum size of the cow community that one AMS may support. A corresponding algorithm was developed for calculating the herd's AMS

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operating time, capacity, and maximum size. Results of the research show that the AMS capability is determined by various factors; the size of the cow community served, time spent on the milking stand, time spent serving milking machines and milk tanks, type of cow traffic to milking, nature of the milking zone etc. The maximum herd size served by an AMS should not exceed 58-59 cows (Priekulis and Laurs, 2012). Cow milking is unquestionably one of the most important economic activities in the Nigerian economy's agricultural sector. It presents a model of an automated milking system, with a view towards adapting it to local means of production. This is derived from a closed form analytical mathematical model that displays the vacuum system as a first order system. For each case the output results corresponded to the desired expectation (Umar *et al*., 2019). To assess the factors influencing the productivity of rotary parlor milking equipment and its correction possibilities. Productivity of rotary parlor milking equipment is influenced by three main factors: The number of milking places on the rotary platform, the fixed speed of rotation or the time of one platform revolution and longer milking period of cows. Methodology for theoretical calculation of the cycle of rotary parlor operation according to the statistical indicators of the milk yield of the herd of the corresponding farm has been developed. To test the methodology also experimental research was performed in four farms, where rotary parlors with 32 to 80 milking places are used (Mangalis *et al*., 2019).

The aim of this study is to show the structure and possibilities of computational procedures compiled into a mathematical model, which as a result provides a clear and objective numerical data for the milking parlor on the farm. This model is to be used as a decision aid to choose the size of a new parlor and optimize the old parlor. The model of calculation was tested and validated under the agricultural production conditions of Egypt. This model can be quite easily modernized and adapted to different local conditions.

Methodology

This study was conducted in three dairy farms in Dakahlia governorate, to design a mathematical model for the performance optimization of milking parlor. The structure of this model is based on the operation of milking parlors, automatic milking system capacity coefficient and estimates of building and equipment costs. There are three main factors that influence parlor selection such as number of cows to be milked, labor available for milking and ability to address future needs. Therefore, only fundamental computational steps and some key operations important for understanding the structure of calculation are presented in this study. The model has been programmed in MATLAB R2018b.

The first farm "A" is representing a dairy farm with 250 cows, equipped with a milking parlor Herringbone 2x10 milking stall. The second farm "B" is representing a dairy farm with 500 cows, equipped with a milking parlor Herringbone 2x16 milking stall. The third farm "C" is representing a dairy farm with 1000 cows, equipped with a milking parlor Herringbone 2x26 milking stall. The three farms components are cow holding hall and milking rooms include the milk tanks with cooling units. Recording time and motion data were obtained by stopwatch and farm computer, therefore, they were reported almost immediately after the last cow is milked.

Model Structure

The structure of this model is based on the needs to find optimization of the milking parlors which include performance and total annual costs. The model basic structure is shown in Figure (1). The calculation consists of many equations.

Model assumption:

Typical recommendations and the assumptions recommended of this model (Maltz *et al*., 2003) are presented in Table (1).

Table 1. Assumption recommended for the model.

Items of model	Assumption	Items of model	Assumption
Times milked per day	3	Building Maintenance (%/yr)	3
Minimum minute in holding pen	45	Building Tax/Insurance (%/yr)	1.5
Turns per hour	4	Life of Equipment (yr)	10
Clean-up hours per day	2.25	Equipment Maintenance (%/yr)	5
Percent cows in milk (%)	85	Equipment Tax/ Insurance (%/yr)	1.5
Discount Rate (%)	9.75	Milk (kg/d per cow)	40
Life of building (yr)	15		

Model design:

The design of the model include three main steps as follows:

The first step is a determination of the characteristics for maximum herd size. The hours per milking can be determination by using Equation (1) as follow:

$$HPK = \frac{T_L HD}{TKD} \quad (1)$$

Where:

HPK **= Hours per milking;**

$T_L HD$ **= Total hours per day to milk;**

TKD **= Times milked per day.**

A major component of parlor efficiency is determined by the number of times each side is filled in an hour. In parlor lingo, this is called the number of turns per hour. The maximum turns per milking is calculated according to Equation (2):

$$M_x UK = U_h * HPK \quad (2)$$

Where:

$M_x UK$ **= Maximum turns per milking;** U_h **= Turns per hour.**

Minimum group for holding pen can be calculated by using Equation (3):

$$M_i G = \frac{HPK}{M_i hp} \quad (3)$$

Where:

$M_i G$ **=Minimum group for holding pen;**

$M_i hp$ **=Minimum minutes in holding pen.**

The parlor designation is calculated from the number of stalls according to Equation (4):

$$NS = \frac{N_{apx} CK}{M_x UK} \quad (4)$$

Where:

NS **= Numbers of stalls;**

$N_{apx} CK$ **= Approximate number of cows in milk.**

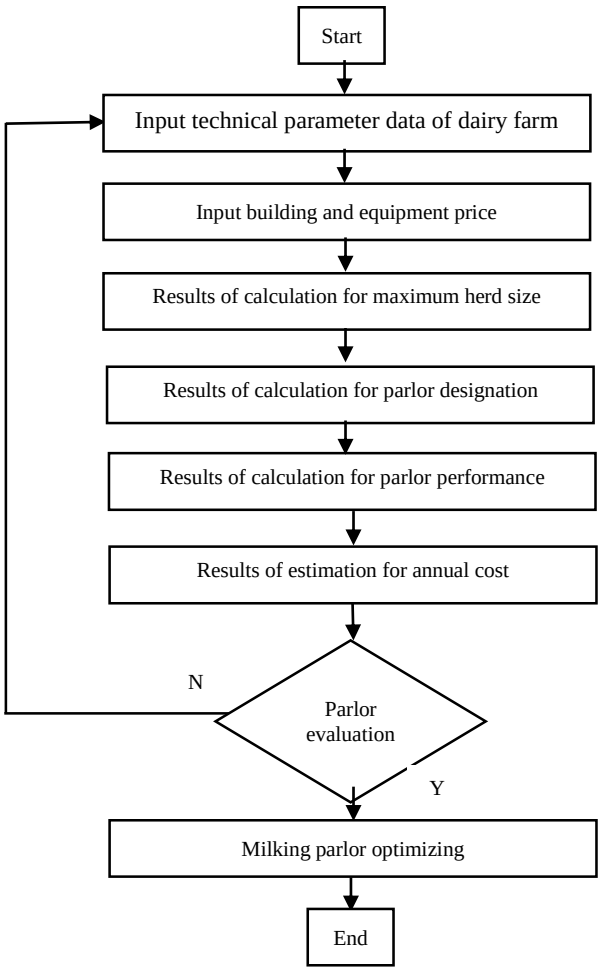

Fig. 1. The basic model structure.

The total turns per milking is calculated by using Equation (5):

$$T_u PK = U_h * TKD \quad (5)$$

Where:

$T_u PK$ **= Total turns per milking;**

TKD **= Times milked per day.**

The Maximum of cows milked is calculated by using Equation (6):

$$M_x CK = NS * M_x UK \quad (6)$$

Where:

$M_x CK$ **= Maximum of cows milked.**

The Cows milked per hour is calculated by using Equation (7). It is calculated by the maximum of cows milked divided by the Hours per milking.

$$CkH = \frac{M_x CK}{HPK} \quad (7)$$

Where:

CkH **= Cows milked per hour.**

The Cows per group is calculated by using Equation (8):

$$CPG = CKH * \frac{M_i hp}{60} \quad (8)$$

Where:

CPG **= Cows per group.**

The Number of groups in fit holding is calculated by using Equation (9):

$$NG = \frac{M_x CK}{CPG} \quad (9)$$

Where:

NG **= Number of groups (fit holding).**

The Actual cows milked is calculated by using Equation (10):

$$ACK = CPG * NG \quad (10)$$

Where:

ACK **= Actual cows milked.**

The Actual hours per milking is calculated by using Equation (11):

$$AHK = \frac{ACK}{CKH} \quad (11)$$

Where:

AHK **= Actual hours per milking.**

The second step is a determination of the parlor performance, to calculate the owner-operator cows per hour maximum possible parlor performance, actual cows per hour performance, number of actual rotations per hour and cows per labor hour. The total cows in herd can be calculated by using Equations (12) as follow:

$$T_L Ch_d = \frac{N_{apx} CK}{CK_{\%}} \quad (12)$$

Where:

$T_L Ch_d$ **= Total cows in herd (w/dry);**

$CK_{\%}$ **= Percent cow in milking.**

The Cows milked per hour per worker is calculated by using equation (13):

$$CKH_{PW} = \frac{CKH}{NW} \quad (13)$$

Where:

CKH_{PW} **= Cows milked per hour/worker;**

NW **= Number of milkers.**

Efficiency in the parlor is significant, but don't compromise milk quality to ensure speedy cow production. The automatic milking system capacity coefficient was calculated according to equation (14):

$$\eta_s = \frac{T_k}{24 - T_w} \quad (14)$$

Where:

η_s **= Automatic milking system capacity coefficient;**

T_k **= Time used for milking cows (h/day);**

T_w **= Time when milking equipment and milk tanks are washed (h/day).**

The third step is an estimation of the milking parlor costs, which include, labor costs, milking equipment costs and consumed supplies. Costs can be calculated by using equation (15) as follow:

$$C_{KP} = C_L + C_E + C_S \quad (15)$$

Where:

C_{KP} **= The final direct costs of milking parlor, LE/ cow. year;**

C_L **= The labor costs per cow and year, LE/ cow. year;**

C_E **= The costs of the milking equipment, LE/ cow. year;**

C_S **= The costs of consumed supplies, LE/ cow. year.**

Annual costs are annualized for depreciation, interest, repairs, taxes, and insurance. Labor costs are calculated on the basis of labor requirements per cow per year and average hourly wage of the milker. Costs of the milking equipment are calculated as specific data of total operating costs of the milking machine converted per one cow. Therefore, it includes the depreciation of machinery, which is the purchase price of the machine expressed by

percentage of machine depreciation, further depreciation of construction that includes construction costs and percentage of building depreciation and the cost of servicing, maintenance and repairs, which are usually expressed as a percentage of planned acquisition costs.

RESULTS AND DISCUSSION

For the objective assessment and selection of milking parlors a lot of different aspects can be used and considered, such as: cow welfare, capacity, price, the number of milkers, reliability, dimensions and complicated construction installation, maintenance and service requirements, and some other aspects.

Optimization of milking parlor:

Farm (A):

Data of the parlor in farm (A) were obtained through field visits in order to verify the validity of the model. The input data in this model at different hours per day to milk for farm (A) are presented in Table (2).

Table 2. Input data of the model in farm (A).

Input data	Farm A
Approximate number of cows in milk, cow	250
Total hours per day to milk, hr/day	10, 12, 15 and 18
Times milked per day	3
Clean-up hours per day, hr/day	2.25
Turns per hour	4
Minimum minute in holding pen, min	45
number of milkers	3

Parlor performance of farm (A):

The results of calculations of the model in farm (A) at 10 hours per day to milk are presented in Table (3). The results are similar to practical reality such as parlor designation was D-10 (milking parlor 2×10 milking stalls). While, the final cows in milk were 260 cows and the number of milker reduced from three to two milker. The automatic milking system (AMS) capacity coefficient was 0.48. Model results showed that, by increasing total hours per day to milk from 10 to 12 hours, the milking parlor 2x10 was decreased to 2x8 and the number of milker remains constant to two milker. The final cows in milk was decreased to 256 and AMS capacity coefficient was increased to about 0.55, as shown in Table (3). Similarly, by increasing total hours per day to milk from 12 to 15 hours, the parlor designation was D-8 (milking parlor 2×8 milking stalls) and the number of milker was two milker. The final cows in milk was increased to 320 and AMS capacity coefficient was increased to about 0.69, as shown in Table (3).

Table 3. Performance summary of milking parlor for farm (A) at different hours per day to milk.

Parlor performance	Model results			
	at 10 hours	at 12 hours	at 15 hours	at 18 hours
Final cows in milk, cow	260	256	320	288
Final hours per day, hr	9.8	12	15	18
Final hours per milking, hr	3.3	4	5	6
Cows milked per hour, cow/hr	80	64	64	48
Cows milked per hour/worker	26	21	21	16
Suggested number of milker	2	2	2	1
AMS capacity coefficient	0.46	0.55	0.69	0.83
Parlor design	D-10	D-8	D-8	D-6

While, by increasing total hours per day to milk from 15 to 18 hours, the parlor designation was decreased to D-6 (milking parlor 2×6 milking stalls) and the number of milkers was decreased to one milker. The final cows in milk was increased to 288 and AMS capacity coefficient was increased to about 0.83, as shown in Table (3).

Cost estimation of farm (A):

The total annual costs calculated based on user inputs. Annualized capital costs are combined with annual labor costs to yield total annual milking cost. The annual costs of various options can then be compared. Estimation of annual costs for the farm (A) at 10 hours per day to milk showed that in case of milking parlor 2x10, the total building and equipment costs were 661,468 L.E/year, the three milking labor cost about 197,100 L.E/year and the total milking operation costs about 858,586 L.E/year, 2,807 L.E/cow and 42,929 L.E/stall, as presented in Table (4).

Table 4. Cost summary of milking parlor for farm (A) at 10 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	61,558	201	3,078
Equipment	599,928	1,961	29,996
Total building and equipment	661,486	2,163	33,074
Milking labor	197,100	644	9,855
Total milking operation	858,586	2,807	42,929

Estimation of annual costs for the farm (A) at 12 hours per day to milk showed that in case of milking parlor 2x10, the total building and equipment costs were 18 % lower than the case of milking parlor 2x8, the two milking labor cost would be reduced by about 26 % and the total milking operation costs were reduced by about 20 %, as presented in Table (5).

Table 5. Cost summary of milking parlor for farm (A) at 12 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	53,529	178	3,346
Equipment	508,413	1,688	31,776
Total building and equipment	561,942	1,866	35,121
Milking labor	156,038	518	9,752
Total milking operation	717,980	2,384	44,874

Estimation of annual costs for the farm (A) at 15 hours per day to milk showed that the total building and equipment costs would be constant, the total milking operation costs increased by about 4 %, the two milking labor cost increased by about 17 %, as presented in Table (6).

Table 6. Cost summary of milking parlor for farm (A) at 15 hours per day to milk.

nnual costs (L.E/year)	Total	Per cow	Per stall
Building	53,529	142	3,346
Equipment	508,413	1,350	31,776
Total building and equipment	561,942	1,493	35,121
Milking labor	188,888	502	11,805
Total milking operation	750,830	1,994	46,927

Estimation of annual costs for the farm (A) at 18 hours per day to milk showed that in case of milking parlor 2x6, the total building and equipment costs were 19 % lower than in the case of milking parlor 2x8, the one milking labor cost would be reduced by about 70 % and the total milking operation costs were reduced by about 28 %, as presented in Table (7).

Table 7. Cost summary of milking parlor for farm (A) at 18 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	46,570	137	3,881
Equipment	427,067	1,260	35,589
Total building and equipment	473,637	1,398	39,470
Milking labor	110,869	327	9,239
Total milking operation	584,506	1,725	48,709

It can be said that, in farm (A) the model reduced the costs of purchasing the parlor designing from 10 to 6 units and reduced the costs of milker from three to one milker.

Farm (B):

Data of the parlor in farm (B) were obtained with field visits in order to verify the validity of the model. The input data in this model at different hours per day to milk for farm (B) are presented in Table (8).

Table 8. Input data of the model in farm (B).

Input data	Farm B
Approximate number of cows in milk, cow	500
Total hours per day to milk, hr/day	12, 15 and 18
Times milked per day	3
Clean-up hours per day, hr/day	2.25
Turns per hour	4
Minimum minute in holding pen, min	45
number of milkers	3

Parlor performance of farm (B):

The results of calculations of the model in farm (B) are presented in Table (9). The results were similar to practical reality such as the parlor designation was D-16 (milking parlor 2×16 milking stalls). While, the final cows in milk was 512 cows. The automatic milking system (AMS) capacity coefficient was 0.55. Model results showed that, by increasing total hours per day to milk from 12 to 15 hours, the parlor designation was decreased to D-14 (milking parlor 2×14 milking stalls) and the number of milkers was constant to two milker. The final cows in milk was decreased to 560 and AMS capacity coefficient was increased to about 0.69, as shown in Table (9).

While, by increasing total hours per day to milk from 15 to 18 hours, the parlor designation was decreased to D-12 (milking parlor 2×12 milking stalls) and the number of milkers was constant to two milker. The final cows in milk was increased of 576 and AMS capacity coefficient was increased about 0.83, as shown in Table (9).

Table 9. Performance summary of milking parlor for farm (B) at different hours per day to milk.

Parlor performance	Model results		
	at 12 hours	at 15 hours	at 18 hours
Final cows in milk, cow	512	560	576
Final hours per day, hr	12	15	18
Final hours per milking, hr	4	5	6
Cows milked per hour, cow/hr	128	112	96
Cows milked per hour/worker	42	37	32
Suggested number of milker	2	2	2
AMS capacity coefficient	0.55	0.69	0.83
Parlor design	D-16	D-14	D-12

Cost estimation of farm (B):

Estimation of annual costs for the farm (B) at 12 hours per day to milk showed that in case of milking parlor 2x16, the total building and equipment costs were 994,426 L.E/year , the three milking labor cost about 234,056 L.E/year and the total milking operation costs were about 1,228,482 L.E/year, 2,039 L.E/cow and 38,390 L.E/stall, as presented in Table (10).

Table 10. Cost summary of milking parlor for farm (B) at 12 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	90,359	150	2,824
Equipment	904,067	1,501	28,252
Total building and equipment	994,426	1,651	31,076
Milking labor	234,056	389	7,314
Total milking operation	1,228,482	2,039	38,390

Estimation of annual costs for the farm (B) at 15 hours per day to milk showed that in case of milking parlor 2x16, the total building and equipment costs were 16 % lower than in the case of milking parlor 2x14, the two milking labor cost would be reduced by about 24 % and the total milking operation costs were reduced by about 18 %, as presented in Table (11).

Table 11. Cost summary of milking parlor for farm (B) at 15 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	81,405	124	2,907
Equipment	772,707	1,173	27,597
Total building and equipment	854,112	1,296	30,504
Milking labor	188,888	287	6,746
Total milking operation	1,042,999	1,583	37,250

Estimation of annual costs for the farm (B) at 18 hours per day to milk showed that in case of milking parlor 2x14, the total building and equipment costs were decreased by 15 % than in the case of milking parlor 2x12, the two milking labor cost would be increased by about 15 % and the total milking operation costs were reduced by about 8 %, as presented in Table (12).

Table 12. Cost summary of milking parlor for farm (B) at 18 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	71,408	105	2,975
Equipment	671,919	992	27,997
Total building and equipment	743,327	1,097	30,972
Milking labor	221,738	327	9,239
Total milking operation	965,064	1,424	40,211

It can be said that, in farm (B) the model reduced the costs of purchasing the parlor designing from 16 to 12 units.

Farm (C):

Data of the parlor in farm (C) were obtained with field visits in order to verify the validity of the model. The input data in this model at different hours per day to milk for farm (C) are presented in Table (13).

Table 13. Input data of the model in farm (C).

Input data	Farm C
Approximate number of cows in milk, cow	1000
Total hours per day to milk, hr/day	15, 18 and 21
Times milked per day	3
Clean-up hours per day, hr/day	2.25
Turns per hour	4
Minimum minute in holding pen, min	45
number of milkers	4

Parlor performance of farm (C):

The results of calculations of the model in farm (C) are presented in Table (14). The results are similar to practical reality such as the parlor designation was D-26 (milking parlor 2×16 milking stalls). While, the final cows in milk was

1040 cows. The automatic milking system (AMS) capacity coefficient was 0.69. Model results showed that, by increasing total hours per day to milk from 15 to 18 hours, the parlor designation was decreased to D-22 (milking parlor 2×22 milking stalls) and the number of milkers was decreased to three milkers. The final cows in milk were decreased to 1056 and AMS capacity coefficient was increased to about 0.83, as shown in Table (14).

While, by increasing total hours per day to milk from 18 to 21 hours, the parlor designation was decreased to D-18 (milking parlor 2×18 milking stalls) and the number of milkers was constant to three milkers. The final cows in milk was increased to 1008 and AMS capacity coefficient was increased to about 0.97, as shown in Table (14).

Table 14. Performance summary of milking parlor for farm (C) at 15 hours per day to milk.

	Model results		
Parlor performance	**at 15 hours**	**at 18 hours**	**at 21 hours**
Final cows in milk, cow	1040	1056	1008
Final hours per day, hr	15	18	21
Final hours per milking, hr	5	6	7
Cows milked per hour, cow/hr	208	176	144
Cows milked per hour/worker	52	44	37
Suggested number of milker	4	3	3
AMS capacity coefficient	0.69	0.83	0.97
Parlor design	D-26	D-22	D-18

Cost estimation of farm (C):

Estimation of annual costs for the farm (C) at 15 hours per day to milk showed that in case of milking parlor 2x26, the total building and equipment costs were 1,681,434 L.E/year , the four milking labors cost about 377,775 L.E/year and the total milking operation costs were about 2,059,209 L.E/year, 1,683 L.E/cow and 39,600 L.E/stall, as presented in Table (15).

Table 15. Cost summary of milking parlor for farm (C) at 15 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	132,656	108	2,551
Equipment	1,548,779	1,266	29,784
Total building and equipment	1,681,434	1,374	32,335
Milking labor	377,775	309	7,265
Total milking operation	2,059,209	1,683	39,600

Estimation of annual costs for the farm (C) at 18 hours per day to milk showed that in case of milking parlor 2x22, the total building and equipment costs were 18 % lower than in the case of milking parlor 2x26, the two milking labors cost would be reduced by about 14 % and the total milking operation costs were reduced by about 17 %, as presented in Table (16).

Table 16. Cost summary of milking parlor for farm (C) at 18 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	117,395	94	2,668
Equipment	1,312,524	1,056	29,830
Total building and equipment	1,429,919	1,151	32,498
Milking labor	332,606	268	7,559
Total milking operation	1,762,525	1,419	40,057

Estimation of annual costs for the farm (C) at 21 hours per day to milk showed that in case of milking parlor 2x18, the total building and equipment costs were 22 % lower than in the case of milking parlor 2x22, the two milking labors cost would be increased by about 13 % and the total milking operation costs were reduced by about 13 %, as presented in Table (17).

Table 17. Cost summary of milking parlor for farm (C) at 21 hours per day to milk.

Annual costs (L.E/year)	Total	Per cow	Per stall
Building	101,202	85	2,811
Equipment	1,075,840	907	29,884
Total building and equipment	1,177,042	993	32,696
Milking labor	381,881	322	10,608
Total milking operation	1,558,923	1,315	43,303

It can be said that, in farm (C) the model reduced the costs of purchasing the parlor designing from 26 to 18 units.

The price of milking parlor in farm (C) is higher because of higher number of milking stalls and larger construction which results just in bigger total annual costs of the milking equipment. The big number of milking stalls is not being used effectively if the milkers follow the milking process exactly and do all the operations. Generally, the organization of milking process in this large type of dairy farms is not easy. It is very probable that in the practical application, time of milking can be longer than results of this calculation due to the time losses and practical problems of movement of dairy cows in the farm and the auxiliary activities in preparation of cows for milking. Finally, it can be concluded that, this model is to be used as a decision aid to choose the size of a new parlor, the number of milker and the number of daily milking hours to suit the conditions of the current farm or newly established farms.

Model Validation:

Validation is the process of evaluating the final software to check whether the software meets the working needs and all forms of testing that involves working with the software and putting it to test. Validation was accomplished by comparing computer model with observed parlor performance. Dairy farm A, B and C provided actual parlor performance data, including the final cows in milk, cows milked per hour, cows milked per hour/worker, suggested number of milker, AMS capacity coefficient and parlor designation. Version of the parlor optimization model (POM) were run using inputs that reflected approximately number cows in milk, total hours per day to milk, times milked per day, clean-up hours per day, turns per hour, minimum minute in holding pen and number of milkers of each validation dairy. Subsequent to model validation, one final and implementable version of the milking parlor optimization model was tested. Table (18) summarizes the comparisons between observed and parlor optimization model for the three farms.

Table 18. Comparison between observed and parlor optimization model for the three farms.

Items	Farm (A)		Farm (B)		Farm (C)	
	Observed	Model	Observed	Model	Observed	Model
Number cows in milk	250	260	500	512	1000	1040
Total hours / day to milk	10	9.8	12	12	15	15
Number of milker	3	2	3	2	4	4
Parlor designation	D-10	D-10	D-16	D-16	D-26	D-26

These results indicated that the computer model provided extremely accurate representations of the mean performance of corresponding real milking parlor systems.

CONCLUSION

The main ideas, principles of calculation and the decision process presented in this paper can be generalized in the following conclusions:

1- The time for milking and the total annual costs of building and equipment are the main parameters which enable evaluation and choosing of a suitable milking parlor for a dairy farm.
2- The calculation for the verification of this model shows that by optimizing of milking parlor, it is possible to reduce the final total annual costs of milking per cow by 30 %.
3- Increased capacity of a dairy farm enables to reduce the final annual costs of milking costs for milking, e.g., the difference between a farm with 250 cows and 1000 cows creates conditions for reducing the final annual costs of milking per cow by 22 %.
4- Evaluation of the existing milking parlors on the farms can help improve the milking process and operations from the point of view of either technical improvement for dairy farm.

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نمذجة نظم الحلب الآلي في مزارع الإنتاج الحيواني

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الهدف من هذه الدراسة هو تصميم نموذج رياضي يمكن استخدامه عند أخذ قرار اختيار المحلب الآلي. تم اختبار نموذج الحساب في ظروف الإنتاج الزراعي في مصر ويمكن تحديثه بسهولة وتكييفه مع الظروف المختلفة. تم التحقق من النموذج الرياضى بشكل أساسي مع بعض النتائج من القياسات في المزارع الثلاثة ذات الأحجام المختلفة لصالونات الحلب ويمكن تكييفها بسهولة مع الظروف المتغيرة. أظهرت نتائج النموذج أنه في حالة المزرعة التي تحتوى على 250 بقرة، تكون عدد الساعات اللازمة للحلب في اليوم 12 ساعة، ويكون تصميم المحلب (8x2). وفي حالة المزرعة التي تحتوى على 500 بقرة، تكون عدد الساعات اللازمة للحلب في اليوم 15 ساعة، ويكون تصميم المحلب (14x2). وفي حالة المزرعة التي تحتوى على 1000 بقرة، تكون عدد الساعات اللازمة للحلب في اليوم 18 ساعة، ويكون تصميم المحلب (22x2). أيضاً أظهرت النتائج أنه بزيادة سعة مزرعة الألبان أمكن تقليل التكاليف السنوية النهائية لتكاليف الحلب، حيث في حالة مقارنة الفرق بين مزرعة تحتوي على 250 بقرة و 1000 بقرة لوحظ انخفاض التكاليف السنوية النهائية للحلب لكل بقرة بنسبة 22٪. ومن تطبيق النموذج نتج أنه يمكن تحسين المحلب الآلى، مع تقليل إجمالي التكاليف السنوية النهائية للحلب لكل بقرة بنسبة 30٪.