Achieving Optimal Cow Performance with the Aid of Information Systems

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Information systems in the dairy herd are used for planning, management, follow-up, and control. Herd data analysis, is a continuously evolving process, in which we need to address the following questions:

a. Diagnosis and alert (what happens?);
b. Retrospective monitoring (what happened?);
c. Retrospective evaluation of causality and economic losses (Why did it happen? What were the losses in production and fertility? What were the economical losses?);
d. The quality of data;
e. From manual observation to automation; and
f. Prediction abilities (what will happen?).

Veterinary medicine had traditionally centered on individual animals. Emerging new problems, being mostly multifactorial and multidisciplinary, called for integrated programs for herd health (Markusfeld-Nir, 1996). To cross the line from individual to herd medicine, data should be recorded and processed, so that both statistical and epidemiological evaluations can be carried out. Herd health monitoring is done on populations, not on individuals. Yet, individual cow data are essential if interactions between factors are to be clarified. Achieving optimal cow performance by drawing operational conclusions from data is the ultimate aim of such a program. Figure 1 describes the relevant data that is processed and the reports that are issued and evaluated. The reports include both monitoring and causal analysis.

MONITORING REPORTS

Ongoing monitoring of herd performance is compared to pre-set targets of performance. Monitoring reports alert against any fall from pre-set targets; and as such should be short, concise, engulf all aspects of herd health, and be issued at regular times (Bartlett et al., 1986). Shortfalls should be further investigated using epidemiological methods.

A partial monitoring of calving traits is presented in Table 1. We routinely issue monitoring reports that deal with production, calving traits and diseases, reproduction, lactation curves, and abortions. The latter also includes a multifactorial analysis that controls the effects of lactation number, trimester of pregnancy, sire, and calendar months.

Table 1. Monitoring report, partial (calving traits), Calving Period: 09/05-08/06.

Calving traits	Primipara		Multipara	
Total calved	159		264	
% Twins	0.0	(0.0)	6.4	(5.1)
% Stillbirth	10.2	(4.7)	10.0	(4.3)
% Milk fever	0.0	(0.0)	5.7	(1.6)

Values in parenthesis are *targets.*

Figure 1. Routine data analysis and reports.

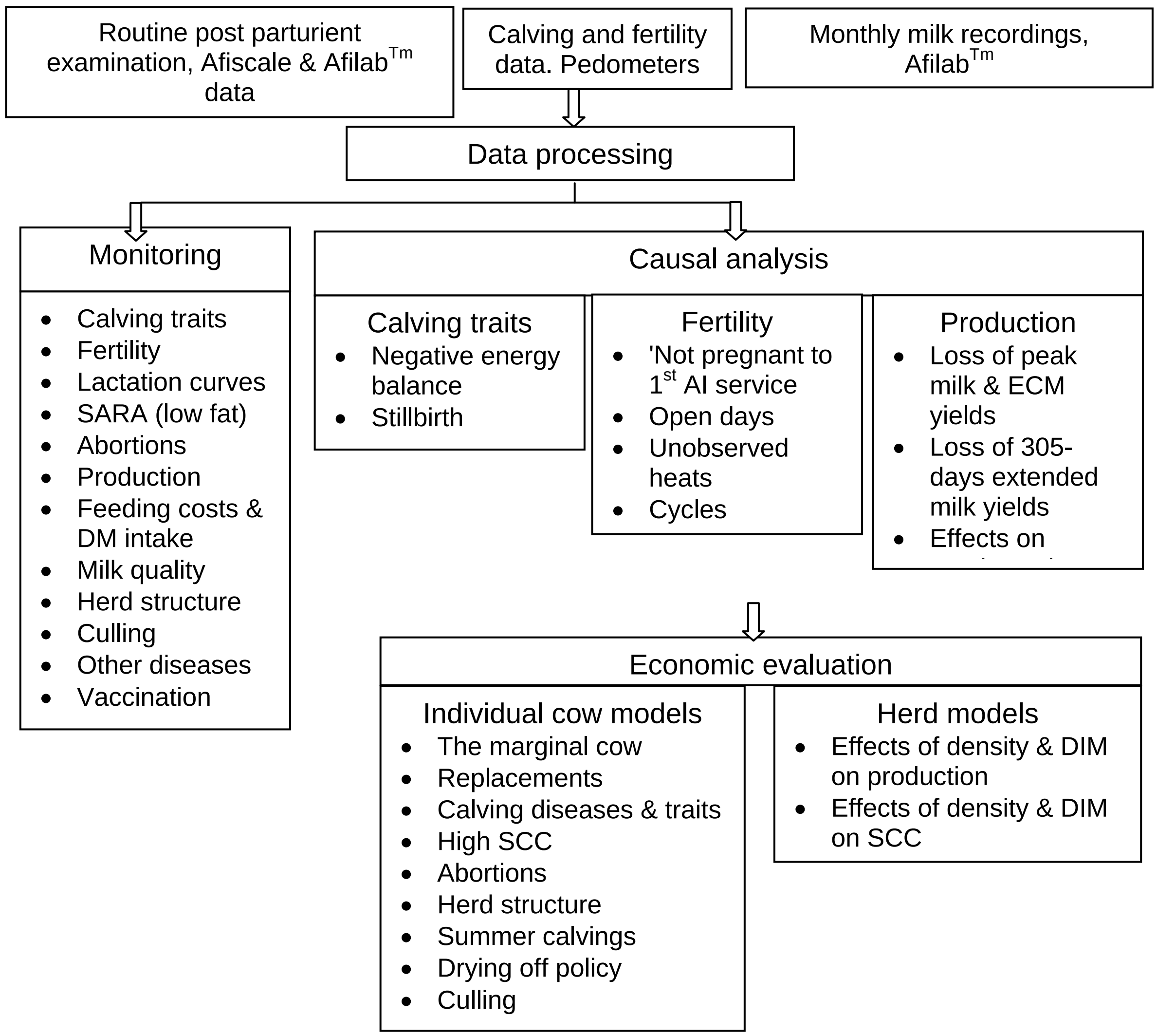
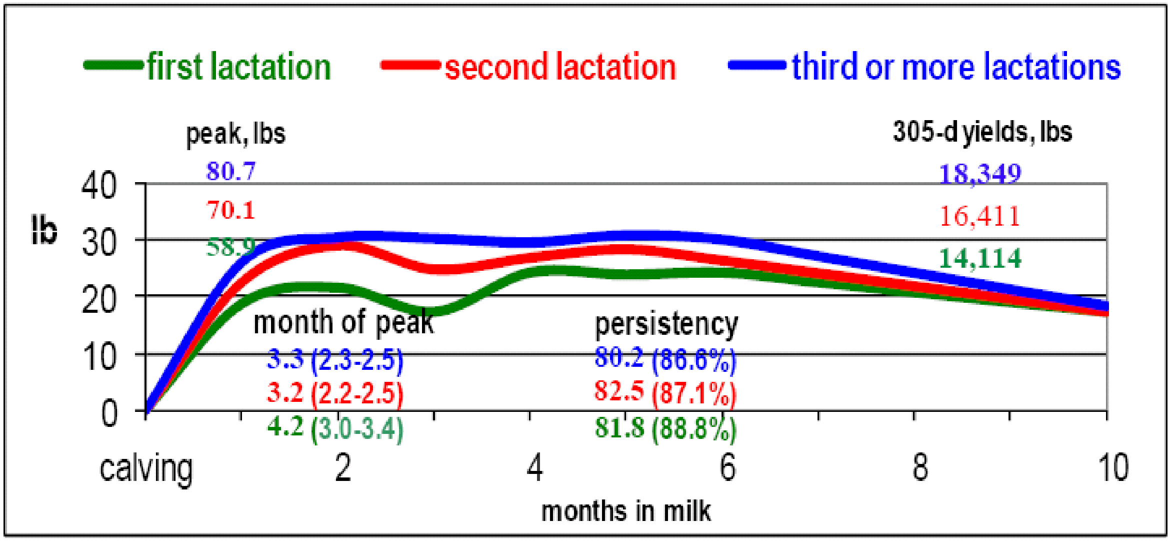


Figure 2. Monitoring lactation curves, a pasture herd using TM Afifeeds (individual feeders). The 2 peaks are the outcome of erroneous concentrate allocation.



Targets are used as a challenge for farmers, they should be within reach and updated regularly. We use 2 types of targets in our reports: a) the best quartiles, and b) desired goals.

Lactation curves, of a South African pasture herd using TM **Afifeeds** (individual feeders) are in Figure 2. The curves monitor the peak and extended 305-d milk yields, months of peak, and persistencies in 3 lactation groups and compare the last 2 to pre-set targets. The double peaks observed in all of the lactations in our sample were the outcome of miscalculation of the extra individual concentrates fed.

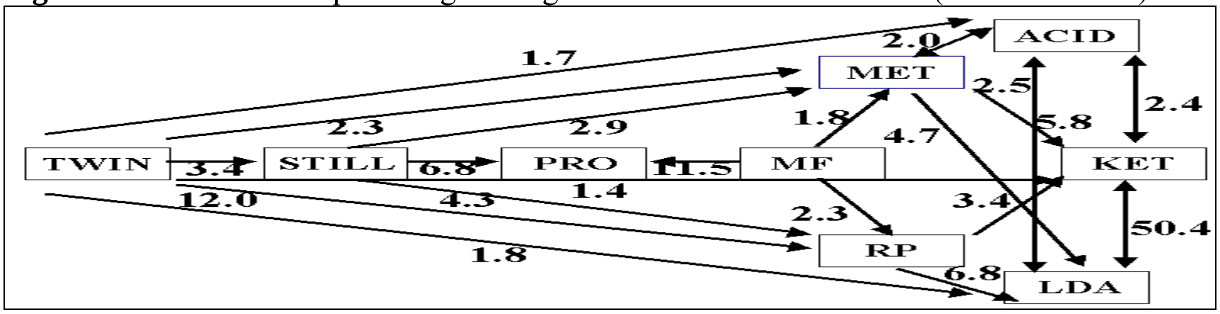
Table 2 describes the risk of abortions by trimester for the period February 01, 2004 –January 31, 2005 in an Italian herd. During the period, 150 embryo losses were recorded (5.0/10,000 cow-days at risk; 7.7 % proportion of aborted cows, 1 aborted twice). Risk of abortion was higher in the third trimester; compared to all other trimesters pooled together (allowing for the effects of parity, calendar months, and sires).

Table 2. Abortions in an Italian herd. A third trimester abortion profile associated with *Leptospira hardjo*. Odds ratios aborting in one trimester compared to all other trimesters pooled together.

Abortions by trimester:	First	Second	Third
Total aborted	16	61	73
Odds ratio	0.7	0.7*	1.9**

*p<0.05; **p<0.01

Figure 3: Interrelationships among calving traits in terms of odds ratios (8521 lactations).



TWIN=twins; STILL=stillbirth; PRO=prolapsed uterus; MF=milk fever; MET=primary metritis; RP=retained placenta; ACID=aciduria; KET=ketosis; LDA=left displacement of the abomasum (after Markusfeld, 1987)

Most abortifacients are trimester specific, establishing the odds risk of aborting in any one trimester of pregnancy might direct the clinician to more efficient laboratory diagnosis (Markusfeld – Nir, 1997). In our sample herd we concluded that brucellosis, chlamydiosis, leptospirosis, salmonellosis, listeriosis, nitrates, vibriosis, or IBR could not be ruled out as the factors responsible (*Leptospira hardjo* proved eventually to be the abortifacient involved).

Diseases Are Multifactorial and Call for a *Multifactorial Approach*

Most production and infectious diseases are multifactorial; and, therefore, call for a multifactorial approach (Nir (Markusfeld), 2008). Figure 3 describes the associations among postparturient diseases and traits in terms of summary odds ratios.

Revealing the Local Truth

Although we manage dairy herds with routines derived from universal experience and published scientific studies, **there is no 'universal truth', but each herd has its own 'local truth'** as illustrated in the following example.

When body condition scoring became a common practice we studied the combined effect (interaction) of the length of the dry period and body condition score (**BCS**) at dry off on future production (Markusfeld et al., 1997). The combined effects of short dry periods and low BCS at dry off resulted in lower production in the next lactation (mainly in terms of fat) independent of the 2 separate effects. The interaction implies that cows with low BCS at dry off will benefit from a longer dry period. We recommend to dry off cows according to their BCS (Nir (Markusfeld), 2003).

With the recent tendency to shorten the dry period, we now routinely evaluate the economic outcome of late drying off of *thin* cows (with BCS below 3.25 units) taking into account the different prices of the ration, extra yield in the present, and loss of milk (if any) in the next lactation, respectively. Such evaluation of the **individual herd** often proves that late dry off leads to a loss of income (Table 3).

Table 3. Loss of income due to late drying off of *thin* cows in an individual herd**.**

Cows with BCS of ≤3.25 at drying off	2nd lactation cows N = 79		≥3rd lactation cows N = 97	
Gestational days at drying off	> 212	≤ 212	> 212	≤ 212
Extended 305-d milk, lb	25,369	27,026	26,288	28,261
Difference, lb	-1,660*		-1973*	
Loss of income (USD)[a]	7,461		9,690	

*p < 0.05
[a]Israeli prices in USD

Correcting Managemental Mistakes and Reduction Losses Attributed to Diseases

We apply routine causal analysis based on regression models on data collected from individual herds in order to expose their *local truth* and to evaluate the contributions of various factors to lower fertility and milk yield in individual herds (Figure 1).

Table 4 sums up the factors that statistically reduced the 305-day milk yields in an individual herd. The results are presented in terms of expected annual extra milk production for the herd (liters).

Improving the Analysis by Introduction of New Variables

Additional variables, when added to the models, could reduce the *common* unknown factors and direct the clinician to better prevention. Figure 4 illustrates the reduction in the contribution of the *common factors* to the trait *not pregnant to first service* when the factor *loss of BCS before service* is added to the logistic regression model.

Quality of Data

Advanced statistical methods could not take the place of complete and reliable data as illustrated in Table 5. In the hypothetical example, the various contributions of metritis to *loss in peak yield* are illustrated. When not all cases of metritis were diagnosed (partial data) cows with metritis produced more milk than cows without the disease. The estimates are different when the complete data set is used, and the *healthy* population does not include hidden cases of metritis.

Feedback to Farmers Encourages Production of Better Data

Improved models and the growing economic benefits derived from them encourage farmers and veterinarians to produce, collect, and record more data that, in turn, lead to better understanding of health problems in a given herd. This is illustrated in Figure 5 that shows the growing number of cows that are body condition scored 3 times during the lactation in Israeli herds involved in the integrated herd health program.

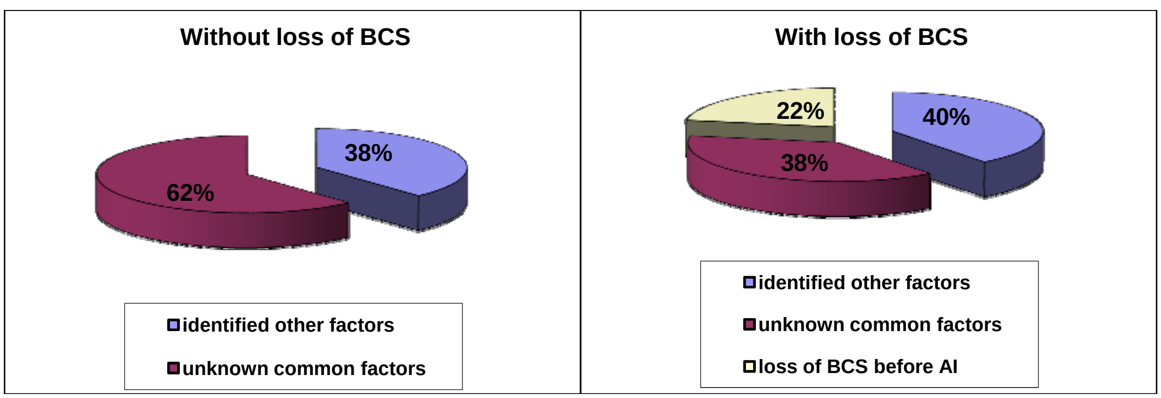
Reliability of Data

Herd health reports are based on data. Some of the variables we use for the causal analysis are subjective; we must both be able to estimate and to improve their quality. Changes in BCS or body weight (**BW**) in various stages of lactation are used to evaluate energy balance of cows over the lactation. We carry an on-going evaluation of reliability and consistency of the 2 measures, the keys to an accurate estimation of the energy balance.

Table 4. Expected annual return of milk (liters/herd) by reducing the adverse effects of managerial mistakes and diseases.

Lactation	First		Second		≥Third		Expected extra production liters/year
	N = 251		N = 233		N = 343		
305-d extended milk yield, lb	22,882		28,704		30,642		
	No. with factor	Diff.	No. with factor	Diff.	No. with factor	Diff.	
Calving diseases	57		46	-530	79		10,753
Summer calvings	72	-791	88		87	-1,415	79,371
Longer dry periods, > 51 (69) d			49	1,711	76	1,694	93,809
Shorter dry periods, < 46 (52) d			72		104	-1,728	79,335
High somatic cell counts	49		22	-794	80	-888	39,046
Negative energy balance	84	-517	78		114		19,102
Expected annual return (liters)			3.3 % of the milk quota				326,443

Figure 4. Non-pregnancy to first AI service. Reduction of the unknown common factors by adding loss of BCS before service to the model.



Others = summer effect, calving diseases, unobserved heat, rest period, dry period; Common = unknown factors (the constant); BCS = lost ≥ 0.5 units BCS from calving to 50 days in milk (**DIM**).

Table 5. Incomplete (hypothetical) data in second lactation cows. Estimates of changes in peak milk yield (lb).

	Complete data		Partial data	
	Incidence/quartile	Milk lost, lb	Incidence/quartile	Milk lost, lb
Calving diseases	37.1	-4.9*	10.3	8.8*
Summer calvings[a]	35.1	-6.2*	35.1	-5.1*
Low BCS at calving[c]	3.00	1.5	3.00	-0.4
Short dry period[c]	61.0	-6.6*	61.0	-8.6**

[a]Calving period April through August (15th October in seasonal herds).
[c]Lowest or highest quarter. Number compared to cow without a factor.
*$p < 0.05$
**$p < 0.01$

Figure 5. Percentages of Israeli cows in the herd health program that are body scored in the various stages of lactation (55,585 cows in 149 herds through 2007).

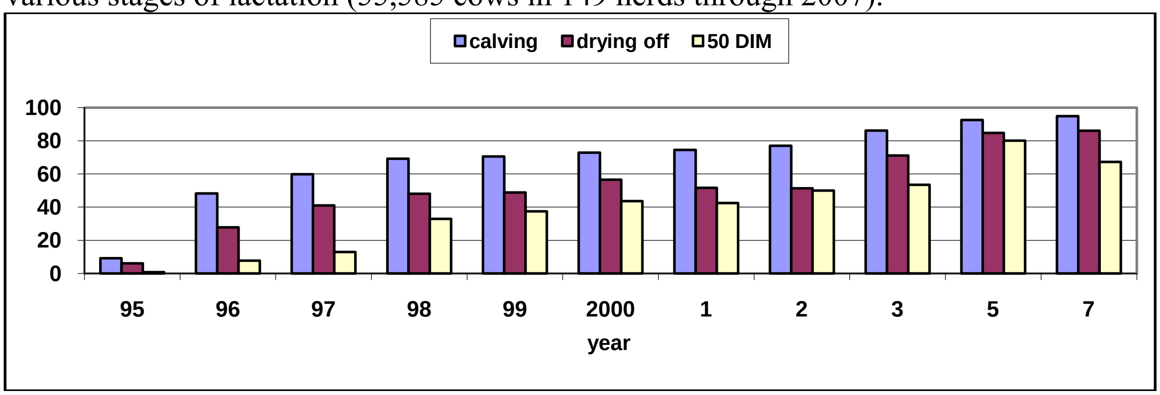


Table 6. Coefficients of correlation between body condition score (**BCS**) and body weight (**BW**) is taken before drying off, after calving, and 40 to 60 DIM (273 multiparous cows).

BCS/BW	At drying off		At 50 days in milk	
	BCS	BW	BCS	BW
At calving	r=.449**	r=.843**	r=.306**	r=.846**

**$p < 0.01$

We use the Spearman rank and Pearson correlation coefficients between 2 sets of BCS and BW respectively as measures of consistencies. Table 6 compares such correlations in data taken from a herd which weighs the cows with the automatic scales AfiWeigh™ and body scores them.

We compared the Spearman rank correlation coefficients between BCS at dry off and BCS at calving of 18 different scorers with at least 5 herds each (Figure 6). It appears that the variations among the various scorers were high, and that **coefficients were typical of the scorers and not of the herds** (compare scorers 1, 7, 8, 16, 22, and 32 to scorers 16, 26, and 34).

Economic Evaluation

We expanded our models to present the results of the causal analysis in terms of financial losses. Economic interpretation allows farmers to set priorities for their resources and investments according to expected returns. Such evaluation is presented in Table 7.

Table 7 is from an Israeli herd, the prices are Israelis, and in US dollars. Losses of income that could be attributed to diseases and managemental factors identified in the herd health report amounted to US$ 303,416 (10.9 % of the estimated income from milk in the period analyzed).

The improvement in an Israeli herd, as expressed by the economic losses, is described in Figure 7 where economical losses (expressed as percentage of income from milk) that could be related to managerial mistakes and diseases dropped from 13.8 to 4.5 % in a period of 30 mo.

From Manual Observations to Automation

More automation will lead to better data, both in quantity and in quality. Afimilk© system has many automated components that replaced, partly or completely, the need for manual observations (milk recording, milk conductivity, pedometers, and automatic scaling).

Figure 6. Ranges of Spearman rank correlations between BCS at drying off and BCS at calving of 18 scorers with at least 5 herds each

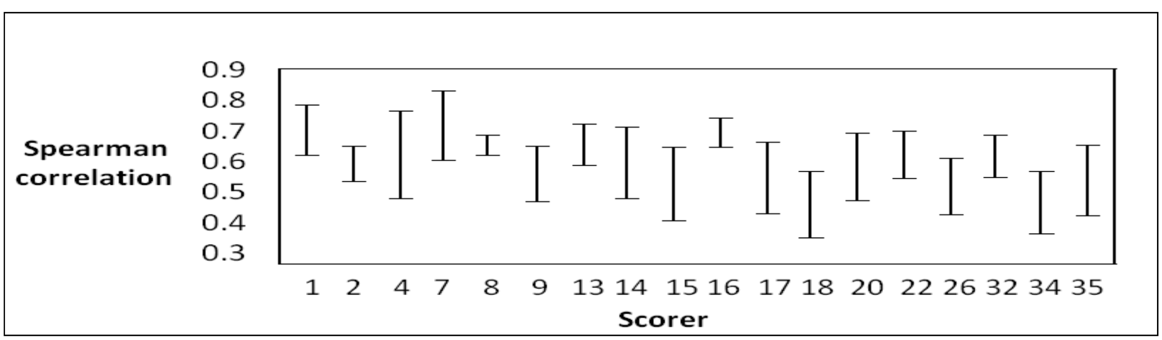


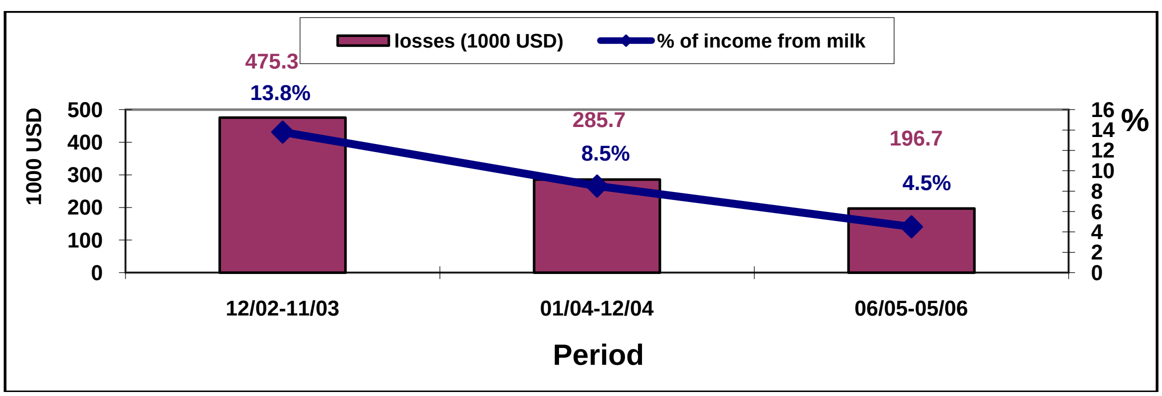
Table 7. Economic losses that could be attributed to mistakes in management and production diseases in an Israeli herd.

Item	Milk	Fertility	Total[1]
Summer calvings	75,921	0	64,988
Long or short dry periods	21,968	677	22,645
Lost BW in the dry period	29,026	0	29,026
Over- or under-conditioned at calving	10,400	1,392	11,793
Calving diseases	22,133	0	37,018
Negative energy balance (**NEB)** at calving	0	0	0
NEB at service	0	13,904	13,904
Unobserved heat	0	9,611	9,611
Long rest period	0	21,043	21,043
Replacements and structure of herd	0	-5,514	22,979
Mastitis	11,370	0	20,365
Abortions	0	6,795	50,045
Total	170,818	47,908	303,416[2]

[1]*includes other expenses*

[2]***10.9 % - of the estimated income from milk***

Figure 7. Improvement example in the Israeli Herd. Annual losses of income attributed to managerial mistakes and diseases (in 1000 US$ and percentages of the estimated income from milk).



More automation is taking place. Some of the applications are now being incorporated in the Afimilk© system. Two are presently described.

AfilabTM - is an in line - on line milk analyzer that performs real-time analysis of individual cow milk solids (fat, protein, and lactose) and gives indication of blood and SCC in every milking. The technology is based on spectroscopy; therefore it does not interfere with milk flow through the line nor does it alter the milk in any way (clean measurement).

A controlled, large scale field trial was carried out in an Israeli commercial dairy herd, milking 800 cows from May through July 2007 (Shkulnik et al., personal communication). Daily milk components from the milk analyzer were compared to those of a reference laboratory.

Daily calculated variations of fat and protein in bulk milk between the AfilabTM and the laboratory were - 0.05 to + 0.28% and 0.01 to 0.05 % respectively. The agreements between the estimated payment returns under Israeli economy corrected milk formulas were -1.1 to 0.0 % and allow for a daily follow-up of dairy returns. Variations of the estimated daily dry matter, intake calculated based upon the NRC 2001 formula, revealed differences of 1.8 MCal/d and 15 gram protein/d/cow between the AfilabTM and the laboratory results.

One of the applications of the AfilabTM is using the daily fat to protein ratio in the milk to diagnose ketosis in the first 35 d of lactation. With improved models, when ketosis was defined as blood level of BHBA > 1.4 mmol/l, Shkulnik et al. (personal communication) were able to establish an 80.9 % sensitivity and an 80.7 % specificity in a controlled field trial involving 395 cows with 21.0 % ketosis (cows with BHBA > 1.4 mmol/l).

Pedometer+TM - is a new leg tag that continuously records activity (number of steps), lying time, and lying bouts. It is based on a 3 dimensional sensor which detects the position of the animal leg. The concept is to determine the routine behavior of the animal (at individual, group, and herd levels) and to define deviations from the daily routine. Such deviations are potential indications for welfare, health, fertility, production, and stressful events. Applications are now under study and implementation.

Applied studies for uses of the behavioral meter showed that behavioral data collected and analyzed may be a useful tool for evaluation and detection of stressful situations (e.g. heat stress, noise disturbance, bedding condition). Derived applications would be monitoring housing management, determing the influence of alteration in farm routine or facilities, and predicting calving time (Arazi, 2008).

Data Used to Improve Performance of Automated Systems: Cycle Distributions (%)

A cycle is the inter-insemination interval. Poor manual or automated heat observation is often blamed for irregular cycles. A preliminary analysis of effects on the first 2 cycles suggested that many *cow factors* (such as summer inseminations, calving diseases, a negative energy balance after calving, use of hormones, and unobserved heat) might affect the cycles' distributions). We now routinely apply

Table 8. Cycle distributions (inter-insemination intervals) in an Israeli herd using pedometers (281 first two cycles in the period 06/05-05/06).

Time Period	June 1, 2005 – May 31, 2006			
Cycles	short	normal	long	double
Range in Days	5-17	18-24	25-36	37-60
Targets, %	6	65	12	17
Actual rates, %	1	50	14	35

regression models which evaluate the effects of various *cow factors* and groups on the risks of short, long, and double cycles respectively. We assume that the *other factors* include those of poor heat detection or more specifically non-calibrated pedometers. Table 8 describes the cycle distributions in a herd using pedometers. Rate of double cycles was high (35.0 %) and above target; and therefore called for further evaluation.

The outcome of that evaluation is in Table 9. *Cow factors* were responsible in our herd for 79.1 % of the double cycles; while poor use of the pedometers could account, at the most, for 20.9 % of them. Reduction of double cycles could be achieved partly by adjusting the threshold to cows according to the known risk factors, but mainly by reducing those factors.

Multidisciplinary and Multi- (among) Herds' Causal Analysis: Stocking Density

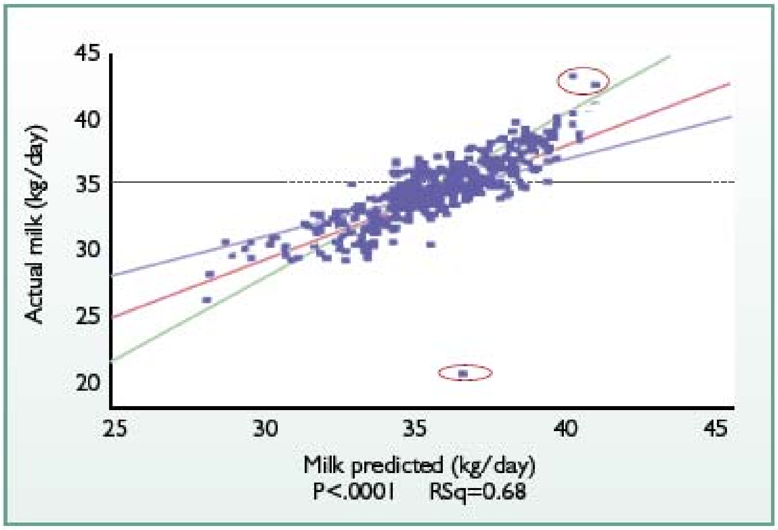
Whole herd models, based on among herds' differences and taking into account production, fertility, health, nutrition, and economics are needed.

Stocking density, mean days in milk (**DIM**), and somatic cell counts (**SCC**), which are linked, should be addressed simultaneously. While the measures of the last 2 are objective, it is very difficult to estimate the stocking density. The recommended indexes (22 m^2/cow in loose stalls, and 100 % cubicles in free stalls) do not necessarily represent the actual stocking density. When we verified that the housing capacity or quality and management of the herd was stable throughout the period analyzed, we then calculated the monthly stocking density (density) as percentages relative to the month with the lowest number of cows in milk in the period analyzed. We estimated the independent effects of the density, DIM, and SCC on yield (kg) from monthly data of actual marketing in a random sample of 19 herds (382 herd months all together) applying a linear regression model, where we allowed for the effects of the various herds, months, and percent of first lactation cows. Figure 8 compares the predicted milk yields derived from the model to the actual ones. Except from those herd months circled, the fit was good and allowed us to apply the model to individual herds.

Table 9. *Cow* and *other* factors responsible for double cycles in an Israeli herd.

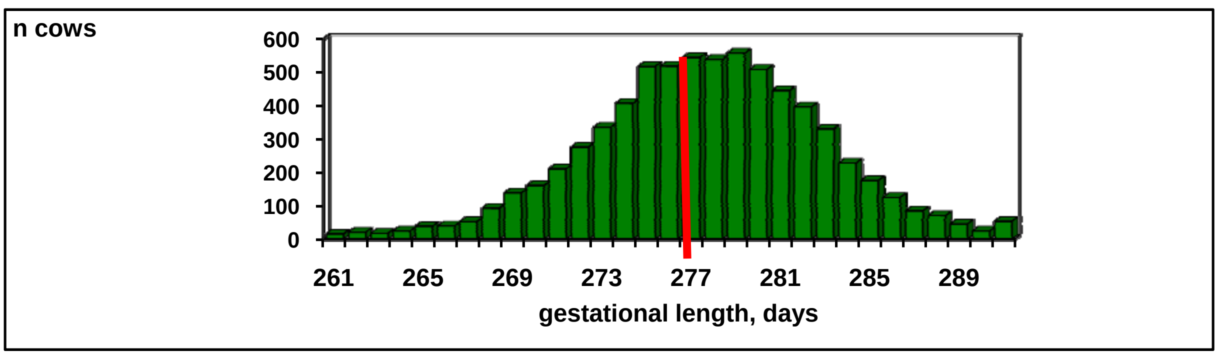
Other factors (include poor use of pedometers)	"Cow" factors		
	Calving diseases	Negative energy balance	Use of hormones
20.9 %	43.8 %	7.2 %	28.1 %

Figure 8. The effects of DIM, SCC, and herd density on daily yield (kg/milking cow) in 382 herd months in 19 herds 2006/07.



International Dairy Topics— Volume 7 Number 6

Figure 9. The distribution of gestational lengths of 6,787 lactations in 34 Israeli herds



We estimated that the respective contributions of density and DIM to the mean monthly milk production were -0.88 lb/10 % increase in density, -1.15 lb/10 DIM, and -1.4 kg/100,000 increase of SCC (Nir (Markusfeld), 2008b) .

Prediction: The Dry Period and the Gestational Length

In a sample of 6,787 lactations of multiparous cows in 34 herds calving in the period 03/2003 through 09/2004, means and standard deviations (**SD**) of dry-off days and the gestational lengths were 68.0 ± 12.0 d and 277 ± 5.3 d, respectively.

The variability of the gestational length is great (Figure 9), at present unpredictable; and therefore cannot be taken into account when drying off cows, which is therefore done under conditions of uncertainty.

We compared the theoretical gestational lengths using linear regression models to the actual lengths; effects of the gestational length, the sires, birth of twins, parity, and the season of the previous pregnancy, as well as the sires, season, and parity of the present pregnancy were included. Terms shorter than 260 days or longer than 290 days were removed from the data set.

Applying the models to individual herds, specificity was high in all herds, ranging from 74.3 to 87.9 % in correct prediction of long gestations, and from 80.2 to 88.1 % in correct prediction of short gestations. The sensitivity found was lower, ranging from 30.8 to 45.0 % in predicting all long gestations, and from 17.3 to 31.2 % in predicting all short gestations. Low sensitivity in predicting short gestations could be explained by the fact that most of them are associated with stress (such as mastitis at calving) which are unpredictable in the future, and usually were not recorded in the past.

CONCLUSIONS

Routine health reports based on epidemiological models are today a common tool used by farmers, veterinarians, and nutritionists. Though experts prepare the reports, their improving quality is the result of routine practice evolved through understanding of the multifactorial nature of modern veterinary issues. Through their postgraduate training, most practicing veterinarians are capable of reading the reports, interpreting them, and implementing the conclusions in their practice. The speaker believes that future progress in applied epidemiology will be in 3 main fields:

a) Improvement of data through automation;
b) Development of multidisciplinary models including economical evaluations; and
c) Improvement of methods applied to small herds.

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