Effect of Cooling Strategies used in Israel on Milk Production, Feed Efficiency and Farm Profitability

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Israel is located in the east of the Mediterranean Sea. Israel's climate is considered subtropical and dry. It is characterized by moderately cool, rainy winters (November–March) and hot summers (June–October), which is the dry season, with no rainfall. Summer is characterized by high temperatures (including the night) combined with high relative humidity in the coast region (daytime temperatures averaging 30°C and relative humidity ranges between 50% and 90%), and is hot and dry in the inland valleys and southern desert (daytime temperatures averaging above 40°C and relative humidity ranges between 20 and 40%).

The Israeli dairy sector consists of near 120,000 *Israeli-Holstein*-breed cows on near 900 dairy farms. These farms are distributed mostly on the coast and in the hot valleys. Based on Israel Herd book data (DHI), which includes near 90% of the dairy cattle in Israel, 2010 average annual milk production was 11,800 kg per cow, with 3.7% fat and 3.2% protein.

Dairy farmers in Israel are well-organized and supported by professional institutions related to the Ministry of agriculture, Universities, Israel Dairy Board, as well as farmer's cooperative companies who supply clinical veterinary care ("HACHAKLAIT") and AI services ("SION"). Israel Cattle Breeders Association (ICBA) owns the local DHI services, based on automatic data flow from the computerized milking equipment. These online reports, elaborated on by the DHI centre, together with a special Dairy Herd Management program (NOA), enable Israeli dairy farmers to make operational decisions and manage their farms efficiently.

In the early stages of the dairy sector development, special production conditions led Israeli dairy farmers to establish a unique and unconventional production concept. This concept is characterized by special and intensive feeding and management practices of cows living in total confinement and in relatively large dairy farms. The strategic decision, taken years ago to obtain high productivity of our cows, was based on the belief that, under Israel's special conditions, a maximization of per cow milk production would be most economically viable. Climatic limitations obliged dairy farmers to develop and implement new technological solutions and special management practices that would facilitate obtaining high milk yields in the hot and humid summers.

The constant rise in cow-milk yields and global warming are boosting the decrease in milk production and cow's reproductive traits. During the last three decades, Israeli researchers have conducted some researches in order to develop an efficient cooling system which will allow obtaining high milk yields and relatively good fertility during the hot season. The technologies for cooling cows developed here have been rapidly adopted by Israeli farmers. Incentive, provided by an appropriate pricing system for milk, has encouraged dairy farmers to install and use these systems extensively. To achieve positive results, proper installation and accurate operation of the cooling system is required. Seasonality in milk supply to the processing industry and market is one of the factors that most influence Israel's dairy sector economy. Due to climatic effects, summer milk production does not reach market demand, and, therefore, winter surpluses are “moved” to be consumed in the summer. Every year, near 40 million liters of milk are “moved” in Israel from winter to summer, with an additional annual cost of 8 million US$ (0.2 US$ per liter). Despite the large economical losses, seasonality in milk supply creates a “political” problem, causing a constant government pressure to replace these “missing liters”, by low price imported milk powder, a step that can affect local farmer’s quota and their annual income. The low reproductive traits, achieved by cows in summer and suspected indirect effect of summer conditions on winter reproductive potential, as was speculated before, are key factors influencing the seasonality in milk supply to the market in summer.

The cooling system largely use in Israel is based on the combination of wetting the cows frequently, followed with blowing air on her through forced ventilation. This system was developed and first implemented in Israel trough cooperation between the Department of Animal Science of the Hebrew University of Jerusalem and the Extension service of the Israel Ministry of Agriculture. The system was first described 25 years ago (1). Cooling the cows 5 times a day, 30 minutes each time, allowed cows, producing 25-30 kg of milk per day to maintain their body temperature below 39.0 C, during all day time, in a typical Israeli summer day.

In the last decade we conducted some surveys, in cooperation with the Israel cattle Breeders Association (ICBA). The aim of these studies was to evaluate the efficiency of the implementation of cooling system in commercial farms located in different parts of the country, on productive and reproductive traits of high yielding cows, performing in the sub-tropical climate of Israel.

The first survey studied the effect of cooling intensity on cow’s productive and reproductive traits. This large scale survey was carried out during four years (1998 –2001) and included 14 farms, near 300 cows each, located in the costal part of the country (2). Farms were classified into three different groups according to the intensity of cooling in summer. Cows of group 1 (six farms, intensive cooling), were cooled in the holding and feeding area for a total of 10 cooling periods and 7.5 cumulative hours per day. Each cooling period combined cycles of sprinkling (0.5 min.) and forced ventilation (4.5 min.). Cows of group 2 (three farms, moderate cooling), were cooled in the holding area only, and were provided a total of six cooling periods and 4.5 cumulative hours per day. Cows of group 3 (five farms, no cooling) were not cooled at all. Milk production (kg/d), was calculated for summer (July-September) and winter (December-February). The analysis included 125,000 milk recordings (> five recordings for each cow per lactation). Average four years daily low and high temperatures (C^o) were 8.4 and 19.3, and 22.0 and 31.8, for winter and summer, respectively. The interaction between season and cooling treatment was significant ($P<0.001$). The ratios between summer and winter daily average milk production were 98.5%, 96.2% and 93.4%, in intensive, moderate, and no cooling treatments, for first calf heifers and 98.5%, 96.1% and 90.7% for adult cows, respectively. The results of this survey are presented in table 1. These results indicate that intensive cooling of cows in the summer can reduces almost completely the seasonal variations in productive traits of dairy cows in summer.

The second survey tried to find out, if intensive cooling in summer has the potential to prevent summer decline in milk production and reproduction of extremely high yielding cows (annual herd average above 13,000 kg). The survey used of 2005 herd book data and included 22 dairy herds, averaging 300 cows each, with total of 6600 cows (3). All dairy herds were located in the coastal part of Israel with same climatic conditions. Cows in all the herds were held under similar housing system, milked 3 times per day and fed for ad-lib, intake a TMR, offered to the cows twice daily. Twelve of the herds were of high and 10 of low production level (previous year winter average milk production of 41 and 35 kg/d, respectively). Cows in half of the herds in each production level group were intensively cooled (IC) during summer, using a combination of wetting and forced ventilation for 10 cooling periods and a total of 7 cumulative hours per day. Cows in the second half of the herds in each production level group were moderately cooled (MC) by a combination of wetting and forced ventilation in the holding pen, only before milking (the minimum cooling that can be found these days in Israeli commercial herds).
As we can see in table 2, Winter (Jan-Mar) and summer (Jul-Sep) milk production averaged 41.5 and 40.7 kg/d, respectively, for the IC herds, and 38.5, 33.8 kg/d, respectively, for the MC herds of the high production level. During the same seasons, in the low producing herds, milk production averaged 36,5 and 36.8 kg/d, respectively, for the IC herds, and 34.4 and 30.2 kg/d, respectively for MC herds.

As extension service, we found through the years, the necessity to create a tool that will permit us monitor the effectiveness of the cooling systems installed in the farms (4). In cooperation with the Israel Cattle Breeders Association (ICBA), we have developed a computerized report, based on the information stored in the "Israeli Herd book", which evaluates the effectiveness of each farm in reducing summer impact on cow's performance. The "Summer to Winter (S:W) performance ratio" report make use of farm's monthly recorded data for milk , milk fat, milk protein, milk somatic cells count (SCC) and conception rate (taking only the first five inseminations for each cow). The higher the ratio is (close or above 1.0) for productive and reproductive data and the lower ratio is for SCC data, the better the farm is dealing with summer heat-stress. The calculations in this report includes the estimates of L.S.M for milk yield, economical corrected milk (ECM), kg/day, fat and protein (%), SCC (000/ml) and summer and winter conception rates (%), for the two seasons, followed by calculation of S:W ratios.
In 2005, S:W ECM ratios above 0.96, 0.90 to 0.96 and below 0.90 were recorded in 34%, 44% and 22% of the dairy farms in Israel, respectively. Summer to Winter milk ratio was 0.94, in 495 small scale family farms averaging 50 cows each and 0.95, in 191 large scale cooperative farms averaging 300 cows each. High, middle and low producing herds (mean winter milk yields of 35.2, 33.1 and 30.2 kg/d, respectively), had S:W milk ratios of 1.03, 0.93 and 0.82. (Table 3). S:W production ratio was above 0.96 in 70% of the farms located in mountain regions (cool weather in summer), compared to only 30% of the farms located in the Jordan Valley (extremely hot regions. The data presented indicates that high producing herds (probably, having better management), obtain also better productive results in summer. The computerized report can provide data analysis on regional and individual farm basis and enables the detection of farms that need improvement of summer management and the provision of necessary consultancy and follow up by extension advisors.

In order to study the rate of improvement in the Israeli dairy sector we calculated the summer to winter ratio for the 200 large scale cooperative dairy farms, and compared it through the years 1994 to 2008. Results are presented in table 4. From the presented in table 4 we can see that, through these years, the average daily milk production was increased by 2.3 kg (6%) in the winter, as compared to the increase of 7.3 kg in the summer (23%). The S:W ratio can represent the advances occurring the Israeli dairy sector due to the proper implementation of cooling means in the Israeli dairy farms.

Based on the S:W ratios from the 2007 report, we tried recently to quantify the overall effect of a better management provided by dairy farms in summer, and intensive cooling the cows, on their annual productive and reproductive results (5). Summer to winter milk ratio for each herd served as the parameter by which we sorted between 24 top farms in Israel and compared them to the 24 farms with the poorest results. We assume that the difference between the productive ratios of these two groups represent the total effect of cooling and better summer management on their annual yield and reproduction traits. Average size of farms in the study was of 400 cows, so the comparison includes near 10,000 cows in each group. Initial averages for productive and reproductive traits for the "high" and "low" ratio groups are presented in Table 5. The fact that average winter milk production was similar in both groups supports the supposition that most of the differences in the S:W ratio among farms in the two groups can be related to the better management in summer in the high ratio group. Least Square Means for Milk, ECM (Economical Corrected Milk), milk fat and milk protein percentage in 305 days of lactation for high and low S:W ratio dairy farms are presented in table 6.
The data presented in table 6, indicates that intensive cooling of high yielding dairy cows under Israeli summer conditions, have the potential to add approximately 700 kg ECM to every cow's lactation, an increase of 6.5% in its annual production. Cows in high S:W ratio herds, calving in spring-early summer reached higher lactation peaks and those calving in winter, persisted better in their lactation, when compared to cows in low S:W ratio farms, probably due to being intensively cooled in summer. In general, we notice ultimately that Israeli cows tend to persist much better in their lactation, as compared to lactations recorded 2-3 decades ago. No doubt that the use of cooling systems in great part of the farms in Israel in last years, is one of the factors influencing this phenomenon. Differently from the achieved in milk production, intensive cooling in high S:W production ratio farms did not eliminate the entire decrease in summer conception rate.

Much information was published in recent years on the negative effect of summer heat stress on the productive and reproductive traits of the high yielding cow. Very limited information existed, till last years, regarding the effect of heat stress on the feed efficiency of cows (as estimated by the feed to milk ratio).
A special 1981 NRC publication showed that maintenance energy requirements of milking cows where 25% higher for cows subjected to ambient temperatures of 35 C , as compared to cows kept at 20 C. If we translate this data to high yielding cows eating ×4 maintenance diets, their expected feed requirements when heat stressed is more than 5% above those of cows in normal conditions.
Researchers from the University of Arizona recently published a study carried out in the new climatic chambers located in Tucson (6). In high yielding cows subjected to normal climatic conditions, whose feed intake was restricted to that of heat stressed cows ,milk yield decline was only half that of heat stressed cows (30% and 15% in the heat stressed and feed restricted cows, respectively). Therefore, the reduction in feed consumption could explain only half of the decline in milk production, assuming that the remaining was energy used for activation of body mechanisms for heat dissipation, in other words, heat stress causes "nutritional inefficiency".

Based on the results from the study in Arizona and making use of it's same experimental procedure , the effects of heat stress and intensive cooling the cows in summer were studied recently by researchers from the Israel ministry of agriculture research and extension services (7). Two groups of high yielding cows, averaging 45 kg/d (100 lib.) were installed in the same side of a barn, fed ad lib, a TMR ration (provided in individual feed boxes weighted daily) and milked 3 times a day. All cows were cooled intensively by a combination of wetting and forced ventilation. The research started on July 1 and until the end of this month all cows were cooled, while feed consumption, milk production and some more parameters recorded. During last week of July, cooling was gradually stopped to one of the groups, while food supply to the other one was restricted (on pair basis) to that consumed by the non cooled, heat stressed ones. As obtained in the "Arizona study", also in the "Israeli study" the 20% decline in feed consumption (from 24.4 to 19.4 kg, 54 to 43 lib. /cow/day), explained only half of the decline and milk production, and milk drop in heat stressed cows was almost double that obtained in cooled ones (14 and 8 kg, 31 and 18 lib. /cow/day), although feed consumption was the same, so it can be said that cooling cows in the summer improve feed efficiency by reducing 5 - 10% the feed required for milk production by heat stressed cows.

Cost effectiveness of intensive cooling the cows in summer was examined under the conditions of the Israeli dairy sector, making use of a special Excel program we developed recently in Israel. This program takes in account the two main "economical benefits", raised from intensively cooling the cows in summer, as shown previously in this article and based on the studies we carried out in Israel, such as the increase in per cow annual milk production and the improve in feed efficiency. The study did not take in account some other economical benefits raised from cooling the cows in summer, such as the increase in milk fat and protein content, the reduction in milk SCC and the improvement in cow's fertility. Economical benefit from these factors (some of them difficult to be quantified), must be added to the economical benefits presented here.

Cost effectiveness of cooling the cows in summer was evaluated under two different production systems. First evaluation was carried out for dairy farms producing under quota system, as it actually exists in Israel. Later on, evaluation was carried out also for production under unlimited conditions, as it exists in many part of the world. In the present lecture, only evaluation of cost effectiveness of cooling cows under no quota (unlimited production) conditions is presented. In our study we assumed that intensively cooling the cows in summer have the potential to increase by 5 - 10% their annual milk production and by 5 - 10% their summer feed efficiency. Under unlimited production conditions, the increase in farm's annual profit is be the differential between the increase in farm's annual income and additional expenses required for achieving it. For this study we made used of the data of typical Israeli dairy herds, where, without using any cooling means in the summer, 273 cows were required to produce the 3,000,000 litres annual quota. By intensively cooling the cows in summer 3,243,000 litres (8% more milk) were expected to be produced by the same number of cows and heifers. Economical benefit under these conditions includes the differential between the increase in farm's income from extra milk produced and improved feed efficiency, after deducing the expenses required for the production of the extra milk (additional feeding, installation and operation of cooling system). Results of this study are presented in table 7. From the presented in table 6 we can see an additional income over feed expenses of 70,000 USD, in intensive cooling dairy farms, as compared to farms without cooling the cows (256 USD/cow/year). To this we add the improvement in feed efficiency due to cooling the cows in summer. The increase in the profit per farm, per cow and per litre of milk produced were calculated after deducing the additional expenses required for the increase in milk production as followed:

- Increased income over feed expenses - 70,000 US$
- Reduced feed expenses (improved feed efficiency) - 30,000 US$
- Total increase in farm's income – 100,000 US$
- Expenses for installation and operation of cooling system - - 20,000 US$
- Net increase in farm's annual profit - 80,000 US$
- Net increase in per cow annual profit - 300 US$
- Net increase in per litre of milk profit - 0.03 US$

From the data presented above we can see that under Israeli conditions, the economical benefit from intensively cooling the cows in summer, reach near 300 USD per cow/year. As mentioned previously, other economical benefits raised from cooling the cows in summer, as the increase in milk fat and protein content, the reduction in milk SCC and the improvement in cow's fertility, can be added to the economical benefits presented in this study, therefore, total benefit from cooling cows in summer is even expected to be higher. It is assumed that, under more extreme climatic conditions and/or poor management practices, as exists in many part of the world, economical benefit from intensively cooling the cows in the hot season can be much higher.

Based on the same methodology and making use of our Excel program, the cost effectiveness of cooling the cows under the conditions of the South of USA (8), the north of Mexico (9), the coastal part of Peru (10), the central part of Argentina and Uruguay (11) and the central dairy regions (MG and SP) in Brazil (12), were evaluated, based on local feed, energy and milk prices.

The increase in per cow annual profit due to intensive cooling the cows in the summer and increasing by 5 and 10%, milk production and feed efficiency is presented in table 8. From the presented in table 8, we can see that, although the differences in level of production and management practices, cooling inputs and milk prices, the increase in the annual per cow profit due to intensively cooling the cows in the summer ranges between 100 and 300 USD, depending in the rate of increase in annual per cow milk production and the improvement in feed efficiency.

We assume that if adding the benefits from improving summer fertility and health traits can increase cows profit by additional 30-40%.

In conclusion:

1. Intensive cooling the cows in the summer can eliminate almost all the summer decline in their milk production.

2. These results can be obtained also in high yielding cows producing more than 13,000 kg annually.

3. Intensive cooling the cows in the summer in Israel increase annual milk production by 700 kg and by 8% of their annual production.

4. Between 1994 and 2008, average daily milk production in the winter increased by 2.3 kg/d and 6%, as compared to an increase of 7.3 kg/d and 23% in the summer.

4. Intensive cooling the cows in the summer can have the potential to reduce, or even totally eliminate the expected 5- 10% decline in feed efficiency (feed to milk conversion).

5. The cost effectiveness of implementing intensive cooling system in the summer was evaluated for the Israeli dairy farm and was found to increase by 30 USD the net annual per cow profit (0.03USD per annual liter of milk produced).

6. The cost effectiveness of implementing intensive cooling systems in different countries in the American continent was evaluated, taking in account the differences in level of production and management

practices, cooling inputs and milk prices,.

7. The increase in the annual per cow annual profit due to intensively cooling the cows in the summer ranges in these countries between 100 and 300 USD, depending in the rate of increase in annual per cow milk production and the improvement in feed efficiency.

8. Economical benefits from improving cow's health and fertility due to intensive cooling are more difficult to quantify, but are expected to increase by 30-40% the calculated profit from adopting the cooling technology in the farm.

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Table 1 – Effect of different intensities of cooling adult dairy cows by a combination of wetting and forced ventilation on their productive traits.

Treatment Parameter tested	Not cooled	Cooled in Holding pen	Cooled in holding pen + feed line
Cumulative cooling time (hours /day)	0	4.5	7.5
Average milk production in winter (kg/d)	38.6	41.4	40.6
Average milk production in summer (kg/d)	35.0	39.8	40.0
Summer decline in milk production Kg/day	3.6 c	1.6 b	0.6 a
Summer : Winter production ratio (%)	90.7	96.1	98.5

Table 2 – Effect cooling intensity in summer on average milk production (kg/d) of dairy cow in farms with high and low production level.

Level of production	High		Low	
Cooling intensity	**Intensive (IC)**	**Moderate (MC)**	**Intensive (IC)**	**Moderate (MC)**
Winter range of milk production (kg/cow/d)	41 - 43	38 - 40	35 – 38	33 - 36
Summer : winter production ratio	0.96 – 1.00	0.86 – 0.88	0.97 – 1.03	0.84 – 0.90
Average milk production (kg/cow/d)				
Winter	42.0	35.3	37.1	39.1
Spring	42.3	36.2	39.1	39.2
Summer	42.0	32.0	38.0	35.7
Autumn	42.1	34.1	38.1	36.9

Table 3 - Effect of production level on summer to winter ratios for economical corrected milk (ECM) of all Israeli herds (2005).

Production level	High (Top 25%)	Medium (Middle 50%)	Low (Low 25%)
Winter ECM production (kg/d)	35.1	33.2	30.2
Summer ECM production (kg/d)	36.1	30.9	24.8
S : W ECM ratio	1.03	0.93	0.82

Table 4 – Average milk production (kg/d) in the summer and the winter and its rate of increase, in large scale cooperative dairy farms in Israel in 1994 – 2008.

Year / Season	Winter	Summer	S:W ratio
1994	37.7	31.0	0.82
2004	39.8	36.5	0.92
2008	40.0	38.3	0.96
Change 2008-1994 (kg)	+ 2.3	+ 7.3	-
Change 2008 - 1994 (%)	+ 6%	+ 23%	-

Table 5 - Summer and Winter averages of milk production and summer to winter ratios in high ratio (intensively cooling) and low ratio (almost not cooling) herds.

Group Parameter	Low S : W ratio	High S : W ratio
No. Herds	24	24
Number of cows (approximation)	10,000	10,000
Winter Milk Production (kg/d)	39.5	39.7
Summer Milk Production (kg/d)	34.4	38.9
Summer : Winter milk ratio	0.87	0.98
Summer : Winter peak lactation ratio	0.90	0.99

Table 6- Average production (305 days) for milk, ECM, milk fat and milk protein, for herds with high and low S:W ratio.

Trait / Group	Low S : W ratio	High S : W ratio	Difference (kg)	Added production (%)
Milk (kg)	11,346	12,017	671	6.0%
ECM (Kg)	**11,081**	**11,807**	**726**	**6.5%**
Milk fat (kg)	402.6	430.1	27.5	6.8%
Milk protein (kg)	360.9	385.3	24.4	6.8%

Table 7 – Milk production, income from milk production and feed expenses in dairy cows from intensively cooling and no cooling farms.

Parameter	No cooling	Intensive cooling	Difference
Cows in the herd	273	273	-
Milk produced (litres/year)	3,000,000	3,243,000	243,000
Income from milk (US$/year)	1,500,000	1,621,000	121,000
Total feed expenses (US$/year)	802,000	834,000	32,000
Milk income over feed expenses (US$)	698,000	768,000	70,000

Table 8 – The increase in annual per cow net profit (USD) due to the proper implementation of an intensive cooling system in different countries of the American continent.

Country / Rate of improvement Due to cooling	**5% increase in milk production and feed efficiency**	**10 % increase in milk production and feed efficiency**
South of USA	150	345
North of Mexico	165	400
Coast of Peru	145	240
Central Argentina (Santa Fe Cordoba)	80	200
Central Uruguay	110	245
Central Brazil (MG and SP)	**145**	**310**