Trop Anim Health Prod (2011) 43:41–49
DOI 10.1007/s11250-010-9652-9

ORIGINAL RESEARCH

Supporting small-scale dairy farmers in increasing milk production: evidence from Morocco

Mohamed Taher Sraïri · Meryem El Jaouhari · Abdessalam Saydi · Marcel Kuper · Pierre-Yves Le Gal

Accepted: 30 June 2010 / Published online: 13 July 2010

Abstract This study aimed to evaluate the effects of technical support provided to five small-scale cattle farms in the Tadla irrigation scheme (Morocco) on their milk yield. The first stage consisted of assessing the initial management of dairy herds, especially feeding strategies, and their effects on milk output. This diagnosis revealed major gaps between the existing and the potential milk yield, due to insufficient and imbalanced dietary rations. Based on this diagnosis, technical support was adapted to the reality of each farm by regularly adjusting the dietary rations to the production potential of lactating cows using available feed resources. The production potential of either pure Holstein or crossbred cows was based on the herd's physiological status and its genetic merit. Results showed that milk production could be rapidly improved by balanced dietary rations that enabled the average milk yield of lactating cows to be reached, while optimising feed costs and reducing the cost of milk production. Providing technical support to dairy farms should have a significant impact on overall milk production at different scales (irrigation scheme, plant supply area, national production) while alleviating the poverty of small-scale farmers. It would require the involvement of farmers' organisations such as milk collection co-operatives to replace services provided by the State, which is currently withdrawing from extension activities.

Keywords Dietary ration · Genetic merit · Milk yield · Nutrients' content · Profitability · Reproductive status

M. T. Sraïri (✉) · M. El Jaouhari · A. Saydi
Department of Animal Production and Biotechnology,
Hassan II Agronomy and Veterinary Medicine Institute,
6 202, Madinate Al Irfane, 10 101,
Rabat, Morocco
e-mail: mt.srairi@iav.ac.ma

M. Kuper
Cirad, UMR G-Eau,
Montpellier F-34 398, France
e-mail: marcel.kuper@cirad.fr

P.-Y. Le Gal
Cirad, UMR Innovation,
Montpellier F-34398, France
e-mail: pierre-yves.le_gal@cirad.fr

Present Address:
M. Kuper
Department of Water, Environment and Infrastructure,
Hassan II Institute of Agronomy and Veterinary Medicine,
6 202, Rabat 10 101, Morocco

Introduction

The recent increase in food demand and the consequences this has for prices have put the world food supply at risk. This particularly concerns animal products such as milk and meat (Nin et al. 2007), with increasing demand in many emerging countries due to changing nutritional habits and demographic growth (Beghin 2006). In order to fulfil the needs, it is widely accepted that a "livestock revolution" is required to increase the supply of animal products worldwide (Delgado 2003). In developing countries, this trend will have to be supported by specifically targeting small-scale farms, which are the main producers in livestock product chains, but whose productivity is often low (Faye and Alary 2001). Recent changes in the dairy sector worldwide emphasise the crucial role played by these farms. For example, India has become the largest milk producer mainly thanks to smallholder systems using domestic breeds and their crosses with imported breeds (Gautam et al. 2010). Eastern European countries still have a large number of small farms despite the privatisation of their dairy sectors (Dries et al. 2009).

The Moroccan dairy sector, which comprises about 700,000 smallholder farms that deliver limited amounts of milk to dairy processing firms every day, shows similar trends. A specific public policy devoted to cattle farming has been implemented since the early 1970s to ensure a supply of animal proteins to the population (Sraïri and Chohin Kuper 2007). This policy enabled the annual raw milk output to be increased from 400,000 in 1970 to 1,600,000 tons in 2008 (MADR 2009). This increase mainly happened in large-scale irrigation schemes where, due to erratic rainfall, water is crucial for fodder production: almost 60% of the raw milk output originates from these areas although they only represent 15% of arable land (Sraïri et al.2009a). However, annual *per capita* availability of dairy products has remained steady at around 40 kg of milk equivalent, which is below international standards, as the increase in milk output has only kept up with demographic growth.

The current national plan for agricultural development (*Plan Maroc Vert* - Green Morocco Plan) expects to triple the domestic milk output by 2020 (up to 5 million tons annually) from current levels, particularly by promoting large agribusiness farms. However, the current production structure raises the issue of the contribution of smallholder farms in achieving that objective. Indeed, these farms have specific characteristics that ensure their efficiency and resilience against milk market volatility such as their dual-purpose breeding practices and low labour costs (Sraïri et al. 2009a). Dairy production provides them with a good income opportunity, but their limited land resources, especially in irrigated perimeters, mean they do not have enough fodder and consequently feed their cows imbalanced dietary rations which have a negative impact on milk yield and profitability (Sraïri et al. 2009b). Increasing their milk production to respond to market demand should be based on improving milk yield per cow rather than increasing the cow stocking rate at farm level, which is already quite high (MADR 2008). Such an increase would require support specifically adapted to the technical and economic situation of these smallholder farms. The new approach should take into account the withdrawal of State services, a trend common to many other developing countries (Kidd et al. 2000). The aim of the present study was to test the possibility to increase the average milk yield of the herd by providing advice to dairy farmers based on close monitoring of their production potential. After describing the study sample and the monitoring methodology, we detail the results based on farm management diagnosis and the impacts of the technical support provided. The value and limits of this approach are then discussed along with its application at a larger scale.

Material and methods

Context

The Tadla large-scale irrigation scheme where this study was conducted is located 200 km south-east of Rabat, the capital city of Morocco. It covers almost 100,000 ha of arable land and accounts for 16% of the annual milk output in Morocco, in addition to other agricultural products such as cereals, industrial crops (sugar beet and olives), fruits and vegetables. Raw milk is produced by around 17,000 cattle farms, which mainly rely on irrigated lucerne grown as fodder on about 25,000 ha. Around 55,000 lactating cows produce 150,000 tons of milk annually with diverse genetic merits: less than 25% are local breeds, almost 75% are either Holstein or Holstein crosses with local breeds. Nearly all the milk comes from smallholder farms, as 80% of the farms cover less than 5 ha of arable land (ORMVAT 2009).

Study sample and methodology

Five small-scale cattle farms were chosen to test the effects of close monitoring of the dietary rations of lactating cows on their milk yield. In accordance with previous studies on the appraisal of livestock systems in developing countries including Cameroon, Pakistan and Peru (Perera 2007), the farms were selected in order to represent the wide range of cattle breeding situations in the region (Le Gal et al. 2009), i.e. (1) specialised dairy farms with pure Holstein cows, (2) mixed farming systems (cattle and cash crops) and (3) dual-purpose herds (milk and meat). The second and third cattle systems mainly use crossbred cows whereas specialised dairy herds imported pure Holstein cows and use artificial insemination (Kuper et al. 2006) (Table 1). Each farm was visited twice a month from November 2007 to May 2008. This schedule enabled the cows' true dietary rations to be compared with their total requirements calculated as the sum of their maintenance and potential production needs. Net energy and protein maintenance requirements were determined in relation with the cows' body weight (Fox et al. 1992). The potential energy and protein requirements for milk production were determined using existing models describing variations in daily milk yield during lactation (Wilmink 1987) and unitary needs to obtain a litre of milk (Vermorel and Coulon 1998). These were related to the herds' genetic merit and their monthly lactation stage (MLS), which was calculated as shown in Equation (1). Calving dates of all the lactating cows were determined during the first visit to the farm in November 2007. Subsequently calving and drying up dates were recorded throughout the monitoring period, and their influence on

Table 1 Structural characteristics of the sample farms

	F1	F2	F3	F4	F5
Arable land (ha)	15.0	6.5	6.5	3.7	6.5
Fodder area (ha)	8.0	4.1	3.5	1.8	4.0
Lucerne (ha)	5.0	2.6	2.6	1.5	3.4
Berseem (ha)	1.0	0.5	0.5	0.3	0.6
Maize (ha)	2.0	1.0	0.3	–	–
Groundwater access	Yes	Yes	Yes	No	Yes
Lactating cows	17	7	5	6	11
Stocking rate (cows/ha of forage)	2.1	1.7	1.4	3.3	2.7
Genetic structure of the herd	Holstein	Holstein	Holstein	Crossbred	Crossbred
Type of cattle farming	Dairy[a]	Dairy[a]	Dairy[a]	Mixed[b]	Dual[c]
Mean milk yield (kg/cow/year)	6,100	4,840	4,600	3,100	2,420

[a] Specialised dairy farm

[b] Mixed farming with cattle and cash crop

[c] Dual purpose (milk and meat) herd

the reproductive status of each herd determined according to Equation (1).

$$\text{Lactation\_stage}_j = \sum_{k=1}^{m} \text{Lactation\_duration}_{k,j} / (\text{Total\_milked\_cows}_j \times 30.4) \quad (1)$$

With:

Lactation_stage_j	Lactation stage (in months) for month *j*
$\text{Lactation\_duration}_{k,j}$	Number of milking days from calving for cow *k* and month *j*
$\text{Total\_milked\_cows}_j$	Total number of milked cows for month *j*

In this work, the genetic merit of pure Holstein herds was considered to be 7,000 kg of milk annually, whereas an annual milk yield of 4,000 kg was used for Holstein crosses with local breeds.

During each visit, all the components (i.e. forage and concentrates) of the cows' dietary rations were weighed. This implied regular evaluation of forage biomass production using a field quadrate method (Martin et al. 2005) throughout the study period. The corresponding value of dry matter (DM) production was estimated using the average value established by Guessous (1991) in the same region for the same crops: lucerne (24%), berseem—*Trifolium alexandrinum*—(12%) and maize (30%). The nutritive contents of the rations were determined using feed composition tables. For concentrates, which were mainly imported, the INRA France table was used (Jarrige 1988), whereas for local fodder (lucerne, berseem and maize) and crop by-products (wheat straw and dehydrated beet pulp), results from Guessous (1991) were used. According to the latter, the average net energy contents of the existing fodder were: lucerne (1.33 Mcal/kg of DM); berseem (1.17 Mcal/kg of DM) and maize (1.03 Mcal/kg of DM).

At each visit, the correspondence between cows' nutritional requirements and the true ration was evaluated using a simulation tool under Excel® (Table 2). Supplementation was suggested to the farmer when a gap was detected between the dietary ration and potential net energy, ruminally degradable protein or metabolizable protein requirements. The two latter parameters related to the protein status of the diet were determined accordingly to the French system of the PDI - *Protéines Digestibles dans l'Intestin*—(Vérité and Peyraud 1988). Calculations assumed that whenever maintenance requirements were fulfilled (i.e. 9.0 Mcal of net energy for a 620 kg Holstein cow and 420 g of proteins—either ruminally degradable or metabolizable), the remaining dietary nutrients would be used to cover the effective dairy production, as a single kg of milk requires 0.76 Mcal and 48 g of proteins (Vérité and Peyraud 1988). The proposed rations took into account the context of the farm, i.e., the availability of on-farm fodder and the money needed to buy concentrates. The acceptance of the suggested balanced rations was tested by monitoring the herds' total milk yield and noting the farmers' opinions about the nutritional changes that were made. The effects on the profitability of dairy production were also assessed. The gross margin of milk production was determined monthly as the difference between milk income and the costs of inputs used to feed the cows.

Results

Farm characteristics and fodder yield

The arable land cultivated by each farm varied from 3.7 to 15.0 ha, of which between 49 and 63% was devoted to fodder (Table 1). All farms relied on a combination of rainfall and surface irrigation, managed by a parastatal agency (*Office Regional de Mise en Valeur du Tadla* (ORMVAT)). In addition, farms F1, F2, F3 and F5 had

Table 2 Assessment of dietary rations distributed to lactating cows (part of Excel® application—Sraïri et al., unpublished)

	Forage and feed concentrates	kg/ cow.day	DM (g/kg)	kg DM/cow.day	Net energy (Mcal/kg)	Total net energy (Mcal)	MP (g/kg)	Total MP (g)	RDP (g/kg)	Total RDP (g)
Forage diet	Lucerne hay	4.25	950	4.04	1.16	4.93	86	365	89	378
	Green lucerne	23.00	200	4.60	0.35	8.05	31	713	35	805
	Wheat straw	–								
Concentrates	Wheat	0.65	880	0.57	1.26	0.82	74	48	92	60
	Dehydrated beet pulp	1.00	890	0.89	1.70	1.70	81	81	61	61
	Compound feed	0.85	930	0.79	1.52	1.29	84	71	84	71
Total ration distributed		–	–	10.89	–	16.79	–	1 278	–	1 375
Maintenance requirements[a]						8.20		373		373
Production allowed by the ration (kg of milk)[b]		–	–	–	–	11.20	–	18.9	–	20.8

Calculating the milk yield per cow allowed by the energy and protein supplies highlights potentially imbalanced rations. Comparing the cow's potential production based on its genetic merit and its lactating status with the yield enabled by the simulated ration allows detection of problems of under- or over-feeding

DM dry matter, *MP* metabolizable protein (g/kg), *RDP* rumen degradable protein (g/kg)

[a] Maintenance requirements for a crossbred cow (Holstein x local breed) weighing 550 kg

[b] Production allowed once the cow's maintenance requirements are covered

access to groundwater, which allowed them to intensify fodder production. Lucerne (almost 72% of total forage area) and berseem (about 15% of forage area) were cropped in all farms. Maize was sown only in farms F1, F2 and F3 on an average of 13% of the total forage area. These farms combined dairy specialisation with access to groundwater, which is indispensable for growing maize (a summer crop) in the context of severe drought and high temperatures (above 45°C) in summer.

Fodder biomass yield was highly variable among farms, revealing differences in the volume of water used for irrigation. Since the study was conducted during a very dry agricultural campaign (only 210 mm of rainfall from September 2007 to August 2008, whereas the average level is 300 mm, and very low reserves in the dams at the beginning of the year) fodder production suffered from some water restrictions. Sometimes no more than 54 m^3 of surface water was allocated per ha per irrigation instead of the official allocation of 864 m^3. Farms F2, F3 and F5, which all supplemented rainfall and surface irrigation with groundwater, were able to reach a total annual yield of 8.0 tons of dry matter (DM) per ha for lucerne, whereas farms F1 and F4 obtained yields of less than 4.8 tons of DM per ha (Table 3). Nevertheless, in all farms, the lucerne yield was quite low compared with the potential yield of 13 tons of DM per ha mentioned by some authors for irrigated conditions in Morocco (Birouk et al. 1997). The berseem yield also varied among farms. Farm F1 produced almost nothing as the farmer preferred to allocate his restricted water volume to lucerne during winter and to maize during spring. Farm F4 harvested berseem only once after the autumn rainfall, and the yield was only 0.6 tons of DM per ha. In the remaining farms, berseem was harvested at least four times from November to May with an overall average yield of 3.1 tons of DM per ha (Table 3). By comparison, maize silage yields in farms F1, F2 and F3 were relatively homogeneous since farmers allocated water mainly to this crop.

Table 3 Forage yields (DM/ha) and their net energy production cost (Euro/Mcal) per farm

	Lucerne		Berseem		Maize	
	DM/ha	Euros/Mcal	DM/ha	Euros/Mcal	DM/ha	Euros/Mcal
F1	4.6	0.08	0[a]	–	10.5	0.05
F2	7.2	0.09	3.2	0.06	9.6	0.08
F3	7.4	0.08	2.4	0.08	9.0	0.08
F4	4.9	0.07	0.6	0.10	–	–
F5	9.4	0.06	3.7	0.05	–	–

[a] Crop abandoned because of water shortage

The production cost of a unit of net energy was evaluated in each farm based on existing references on the average net energy content of each crop, their respective yields in each farm, and the amounts of inputs used for their production (cost of irrigation water, fertilisers, pest treatments, harvesting, etc.). A single Mcal of net energy from the existing irrigated fodder crops costs from 0.05 to 0.10 Euros (Table 3), compared with 0.17 Euros per Mcal for grain maize based on a purchase price of 0.32 Euros per kg during the study and 1.9 Mcal of net energy per kilogramme (Robinson et al. 2004). This gap highlights the advantage farmers have if they produce their own forage, especially since (1) highest levels of yields enable the production cost of net energy to be reduced, as shown in Table 3 and (2) legume fodder crops such as lucerne and berseem also supply protein, which is indispensable for lactating cows.

Characterising the reproductive status of lactating cows

Changes in the reproductive status of each herd revealed clear differences among farms (Table 4). Farms F1 and F2 had imported full Holstein heifers in June 2007 and calving occurred during autumn. These herds' MLS consequently increased steadily by almost one unit from November 2007 to May 2008. The F3 herd consisted of Holstein cows imported since 1999. At the beginning of the study, they were being milked for the 11th month and the farmer was about to cull them because of frequent reproduction failures. He had two heifers in calf and planned to purchase other cows from the local market. Therefore, the replacement of old cows led to a sharp decrease in the MLS at the beginning of the monitoring period. Farm F4 had two calvings in January 2008 and a drying up in April 2008, explaining the relative stability of the MLS of the herd with an average value of 8 months throughout the year. Finally, farm F5 had a calving almost every month, which explains the slow increase in the herd's MLS over the study period. The consequences of the changes in the herd MLS on the potential daily milk yield per cow were determined, assuming that in farms F1, F2 and F3, the cows were pure Holsteins, while in farms F4 and F5, herds were made up of crossbred cows (Table 4). This combination of average physiological status and genetic merits of cows resulted in acute variability of the monthly lactation potential of each herd.

The impacts of the support programme on the herds' milk yield and economic results

The initial characterisation of lactating cows' dietary rations at the beginning of the study revealed insufficient and imbalanced supply between energy and ruminally degradable protein in all farms. In fact, the main forage supplied is green lucerne, which provides more protein than energy with respect to the average cow's net energy maintenance requirements. Table 5 shows an example of the dietary rations used in farm F1 for pure Holstein cows with a lactation potential of 27 kg of milk daily and an average body weight of 620 kg at the beginning of the monitoring period. This ration is largely representative of the situation observed in the other pure Holstein herds in this study. It is characterised by an insufficient supply of DM, which varies between 6 and 8 kg of roughage per cow, whereas a Holstein cow could ingest as much as 15 kg of DM from good quality lucerne (Castillo et al. 2006). And it is unbalanced, as lucerne and berseem, two leguminous plants, represent the bulk of the initial roughage intake,

Table 4 Changes in monthly lactation stage and equivalent lactation potential (kg/lactating cow.day) in the five study herds

	Nov. 07	Dec. 07	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May 08
F1							
MLS	3.6	3.7	3.9	4.8	5.4	6.2	7.8
LP	27	26	26	24	22	20	18
F2							
MLS	2.1	3.0	4.0	4.8	5.7	6.6	7.6
LP	31	29	26	24	22	20	18
F3							
MLS	10.0	11.1	4.9	5.8	6.0	3.8	7.0
LP	10	10	23	21	19	24	17
F4							
MLS	7.0	8.3	8.8	7.0	8.0	7.5	8.5
LP	11	10	8	11	10	10	9
F5							
MLS	2.5	3.0	4.0	4.3	4.7	5.2	5.7
LP	18	17	15	14	14	13	12

MLS monthly lactation stage (in months), *LP* lactation potential (kg of milk/lactating cow.day)

Table 5 Dietary rations used in farm F1 at the beginning of the monitoring period and the corrected ration in relation to the herd's potential production

	Ingredients	kg/cow.day (DM)	Net energy (Mcal)	Metabolizable protein (g)	Rumen degradable protein (g)
Forage	Green lucerne	4.2 (6.8)	5.59 (9.06)	292 (473)	367 (594)
	Maize silage	2.3 (2.3)	2.37 (2.37)	145 (145)	127 (127)
	Wheat straw	1.2 (1.8)	1.04 (1.56)	62 (93)	32 (48)
Concentrates	Maize grain	3.5 (3.5)	7.41 (7.41)	420 (420)	296 (296)
	Beet pulp	1.6 (3.2)	2.93 (5.86)	167 (334)	125 (250)
Nutrient supply	–	–	19.34	1,086	947
Maintenance	–	–	9.00	420	420
True milk yield (kg/cow.day)	–	–	13.20	13.88	11.00
Effective milk yield (kg/cow.day)	–	–	22.65	22.78	18.65

leading to a relative excess of ruminally degradable protein whereas net energy is lacking. The amount of both energy and metabolizable protein supplied were thus insufficient to cover total requirements (i.e. maintenance and potential production). For that reason, this dietary ration was not suitable to reach the lactation potential of the herd.

Supplementation of the initial ration was thus proposed to improve the herds' average milk production. This consisted mainly in adding sources of degradable energy in the diet, such as dehydrated beet pulp or maize grain, and if possible to increase the supply of lucerne, which is a cheap source of nutrients. Table 5 shows the proposed ration with a balanced supply of nutrients to match the herd's potential production. In 1 month, supplementation increased the volume of milk per lactating cow in the herd from 11 to 19 kg, by supplying the adequate amounts of net energy and metabolizable protein. The concept of balancing the supply of nutrients in the dietary rations with changes in the herds' potential requirements was maintained in the five herds throughout the study period. Alternative forage such as on-farm reserves of lucerne hay, berseem, green lucerne purchased from neighbouring farms or maize silage, were used during the cold months of December and January when lucerne almost stops producing biomass. The effects of constantly correcting the dietary rations are shown in Fig. 1. Farm F1 adopted the strategy straight away and reached a milk yield equal to the potential milk capacity of the herd after three months (Fig. 1).

The farmer of farm F1 was able to judge the effects of the method on the profitability of the dairy herd (Table 6). Similar results were obtained by the two other specialised dairy farms, F2 and F3. Since all three farmers were able to purchase lucerne from neighboring farms, we explained that this roughage provided nutrients (energy and proteins) that were cheaper than those available in purchased concentrates. The support process was also successful in farm F4 with crossbred cows, but it took more than 5 months to reach its potential milk yield (Fig. 1). This result highlights the quicker response of purebred Holstein cows to improved rations than that of crossbred cows. This can be explained by their better milking ability which allows them to convert nutrients in the diet into milk more efficiently than other breeds (Delaby et al. 2009). Increasing milk production to reach the potential allowed the milk production costs to be reduced below the farm gate milk price (0.27 Euros/kg), making this activity profitable before the calves were sold. However, the method failed with F5, the farmer did not agree to change his practices as he preferred to maintain a balance between milk and meat production rather than increase the milk yield of lactating cows. In his case, the gross margin of milk production remained negative throughout the study period and livestock income came mainly from sales of cattle.

Discussion

This study showed that close monitoring and a support process with a particular focus on the nutrient supply in the dietary rations of lactating cows throughout the year may help increase the milk yield and improve the profitability of the herd on small-scale cattle farms. Firstly, the monitoring process provided insights to explain why the cows' productivity was below their genetic potential. The main reasons were (1) the low productivity of forage crops, especially lucerne, (2) the high animal stocking rate, with an average of 2.2 cows and their progeny per ha of forage, which creates rather conflicting situations between feeding either growing animals or lactating cows using existing on-farm feed resources, (3) imbalanced rations between energy and protein supplies, which underlines the farmers' lack of knowledge regarding the principles of cattle feeding, (*iv*) the strategic choices of farmers in relation to cattle rearing (specialised versus dual purpose livestock system) and their investment capacity in high genetic merit dairy cows.

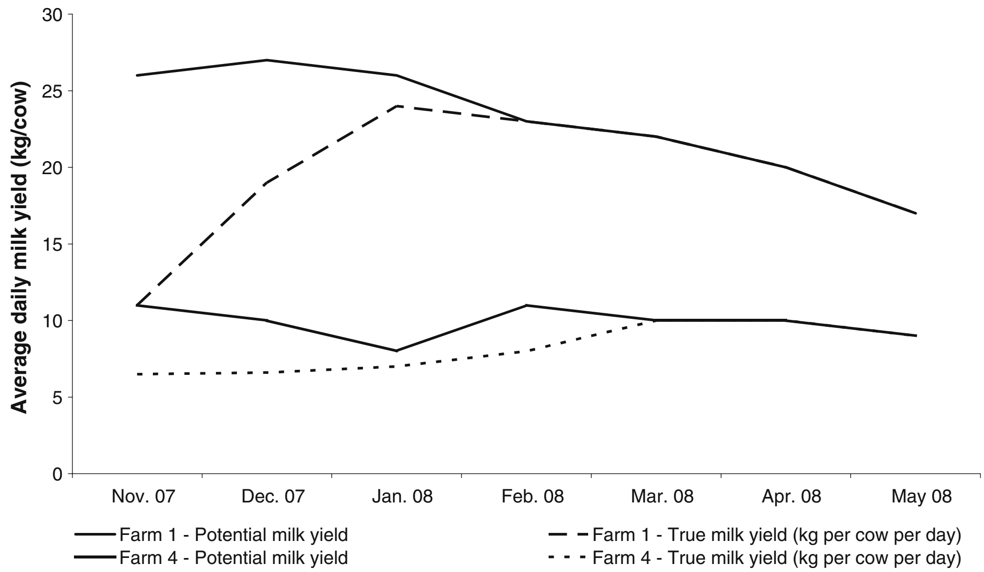

Fig. 1 Effect of the diet support programme on the average milk yield per cow for purebred Holstein cows (Farm 1) and crossbred cows (Farm 4)

Secondly, the support component of the process suggested how to provide balanced rations to improve milk productivity depending on the cow's potential throughout the study period. The method was based on a user-friendly simulation tool and a good knowledge of each herd, taking into account their calving dynamics and the genetic merit of the cows. This balancing process requires calving management to be synchronised with feed supply in order to maximise milk yield according to the herd's genetic merit (Val-Arreola et al. 2004). Managing the relationship between the demand and supply of feed is rather complex at farm level since it involves a range of operational, tactical and strategic decisions. For example, calving strategies are difficult to implement in small herds where insemination failures delay milk production. Feed supply includes decisions such as selection and management of forage crops, design of dietary rations including concentrates, purchase of forage and concentrates available on the market. In parallel to the study presented here, a specific simulation tool was developed to address these complex issues and to support farmers in designing new cattle management strategies including such varied decisions (Le Gal et al. 2009).

Balancing rations showed that it was possible to increase milk production and to simultaneously decrease production costs by targeting different feeding strategies mixing fodder and purchased concentrates. The rapid and reliable impact of the support process on the profitability of dairy production in small-scale farms showed that such production structures are compatible with industrial dairy supply chains in emerging and developing countries, as long as they can benefit from some support and from input supply services (Arriaga-Jordan et al. 2002). But the milk supplies required by industrial dairy plants as well as the expected regional impact of dairy production on poverty alleviation imply that a large proportion of farmers must be reached if the existing situation is to be significantly improved (Bayemi et al. 2009). This study revealed certain limits of such an approach. It was conducted on a very small sample of farms and was based on labour-intensive interventions: bi-monthly visits, direct measurement of critical variables that are rarely estimated by small-scale farmers, such as forage productivity, good knowledge of the farms visited, use of a simulation tool in a one-to-one relationship between researchers and farmers. The support process should now be experimented at a larger scale (such as an area that supplies a dairy plant), to evaluate its feasibility and impacts. In the Tadla perimeter, State withdrawal from extension activities means that this change of scale would

Table 6 Changes in the daily gross margin per lactating cow and milk production cost during farm monitoring

	F1	F2	F3	F4	F5
IGM_0 (Euros/day)	−0.4	−2.2	−1.5	−0.3	−1.0
AGC (Euros/day)	0.3/0. 8	0.2/0.7	0.4/3.0	0.04/0.8	−0.6/−1.0
IPC_0 (Euros/kg)	0.34	0.31	0.41	0.34	0.46
APC_a (Euros/kg)	0.17	0.22	0.27	0.23	0.41

IGM_0 initial gross margin per cow, *AGC* average gross margin per cow after calculation of balanced dietary ration, *IPC_0* initial production cost of a kg of milk, *APC_a* average production cost of a kg of milk after calculation of balanced dietary rations

involve dairy collecting co-operatives managed by the farmers themselves, perhaps with the support of the dairy industry, as the latter urgently requires higher flows of good quality milk. The milk collection cooperatives already provide inputs such as feed concentrates and they could also recruit technicians to provide advice to their members based on a fee collected on each kg of milk delivered. Similar experiments have been conducted in West Africa with cotton-based farms and showed the importance of taking into account the different components of an advice institution in agriculture (governance, funding, training, advice methodology, advice tools) (Faure and Kleene 2004). Such institutions should facilitate the design of suitable advice tools and the collection of local references on dairy and fodder production which are needed to provide efficient support to local dairy farmers (Pacheco 2006). The institutions should focus their support activities on farmers who wish to improve their milk yield like the specialised farms in our sample, since some farmers prefer to diversify their income by combining dairy production with other products such as meat or crops.

Conclusion

This study shows that small-scale dairy farms can significantly increase their average milk yield per cow and the overall profitability of cattle rearing by improving their feeding practices. This result was achieved by implementing consistent monitoring of and providing support to five farms in order to guarantee that the nutrients supplied by dietary rations are adapted to changes in the potential productivity of the herd over time. The support process was successful in farms that specialised in dairy production or were interested in improving their milk yield, whereas it was a failure in a farm that was more orientated towards fattening suckling calves. The support programme necessitated the monitoring of all the parameters involved in the elaboration of the herd's milk yield, from the characteristics of lactating cows (genetic merit and reproductive status) to on-farm forage production. It included the use of a simulation tool to design balanced and sufficient dietary rations. The whole process requires a relationship of confidence and proximity between researchers and farmers who need to be convinced by significant results in both an improvement in milk yield and an increase in the gross margin obtained from the dairy activity.

Given the current lack of technical support to farmers after the withdrawal of State technical services, knowledge concerning small-scale dairy production circulates with difficulty, mainly through informal networks. Building an innovative support service devoted to smallholder livestock production farms would facilitate collecting local references about dairying and making further improvements in the overall milk output. Indeed, this study shows that small-scale dairy farms can easily improve both their production and profitability when such a service is provided. Milk collection co-operatives, who play a strategic role in the dairy chain as an intermediary between farmers and industrial dairy processors, could be in charge of this support activity. This would require arrangements between all the stakeholders of the supply chain to cover the costs of such a service (which would benefit them all), based on an increasing amount of raw milk delivered by farmers to processors through the milk collection co-operatives. Such a scheme should be feasible in different contexts worldwide where dairy production is based on an association between small-scale farmers and industrial dairy processors.

Acknowledgments This study was conducted with the support of the SIRMA project (Water Saving in Irrigation Systems in North Africa), financed by French institutional co-operation and North African countries. The authors address their thanks to the farmers for their kind collaboration in the support process. Last but not least, the support provided by the Tadla Regional Authority for Agricultural Development (ORMVAT) is duly acknowledged.

References

Arriaga-Jordan, M., Albarran-Portillo, B., Espinoza-Ortega, A., Garcia-Martinez, A. and Castelan-Ortega, O.A., 2002. On-farm comparison of feeding strategies based on forages for small-scale dairy production systems in the highlands of central Mexico, Experimental Agriculture, 38, 375–388

Bayemi, P. H., Webb, E. C., Ndambi, A., Ntam, F. and Chinda, V., 2009. Impact of management interventions on smallholder dairy farms of the western highlands of Cameroon, Tropical Animal Health and Production, 41, 907–912

Beghin, J.C., 2006. Evolving dairy markets in Asia: recent findings and implications, Food Policy, 31, 195–200

Birouk, A, Bouizgaren, A. and Baya, B., 1997. Luzerne (Medicago sativa). In: G. Jaritz and M. Bounejmate (eds), Production et utilisation des cultures fourragères au Maroc, (INRA Éditions, Rabat, Morocco), 129–136

Castillo, A.R., Taverna, A.M., Páez, R.R., Cuatrin, A., Colombatto, D., Bargo, F., García, M.S., García, P.T., Chavez, M., Beaulieu, A.D. and Drackley, J.K., 2006. Fatty acid composition of milk from dairy cows fed fresh alfalfa diets, Animal Feed Science and Technology, 131, 241–254

Delaby, L., Faverdin, P., Michel, G., Disenhaus, C. and Peyraud, J.L., 2009. Effect of feeding strategies on performances and their evolution during lactation of Holstein and Normande dairy cows, Animal, 3, 891–905

Delgado, C.L., 2003. Rising consumption of meat and milk in developing countries has created a new food revolution, Journal of Nutrition, 133, 3907 S–3910 S

Dries, L., Germenji, E., Nivelin, N. and Swinnen, J.F.M., 2009. Farmers, vertical coordination, and the restructuring of dairy supply chains in Central and Eastern Europe, World Development, 37, 1742–1758

Gautam, Dalal, R.S., Pathak, V., 2010. Indian dairy sector: Time to revisit operation flood, Livestock Science, 127, 164–175

Faure, G. and Kleene, P., 2004. Lessons from new experiences in extension in West Africa: management advice for family farms and farmers' governance, The Journal of Agricultural Extension and Education, 10, 37–49

Faye, B. and Alary, V., 2001. Les enjeux des productions animales dans les pays du Sud, INRA Productions Animales, 14, 3–13

Fox, D.G., Sniffen, C.J., O'Connor, J.D., Russell, J.B. and Van Soest, P.J., 1992. A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy, Journal of Animal Science, 70, 3578-3596

Guessous, F., 1991. Production fourragère et systèmes animaux, (Actes Éditions, Morocco)

Jarrige, R., 1988. Table des valeurs nutritionnelles des aliments. In: R. Jarrige (ed), Alimentation des bovins, ovins et caprins, (INRA Éditions, Paris, France), 351–443

Kidd, A.D., Lamers, J.P.A., Ficarelli, P.P. and Hoffman, V., 2000. Privatising agricultural extension: *caveat emptor*, Journal of Rural Studies, 16, 95–102

Kuper, M., Le Gal, P.-Y., Moulin, C.-H., Puillet, L., Sraïri, M.T. and Elbahri, M., 2006. Typologie et modélisation des étables laitières dans le périmètre du Tadla, (CIRAD, Montpellier, France)

Le Gal, P.-Y., Kuper, M., Moulin, C.-H., Sraïri, M.T. and Rhouma, A., 2009. Linking water saving and productivity to agro-food supply chains: a synthesis from two North African cases. Irrigation and Drainage, 58, S320–S333

Martin, R.C., Astatkie, T., Cooper, J.M. and Fredeen, A.H., 2005. A comparison of methods used to determine biomass on naturalized swards, Journal of Agronomy and Crop Science, 191, 152–160

MADR (Ministry of Agriculture and Rural Development), 2008. Plan Maroc Vert : premières perspectives sur la stratégie agricole, (Rabat, Morocco). Available at: http://www.vulgarisation.net/Plan_Maroc_Vert.pdf. Accessed March 29th, 2010

MADR (Ministry of Agriculture and Rural Development), 2009. L'élevage en chiffres, Rabat, Morocco

Nin, A., Ehun, S. and Benin, S., 2007. Livestock productivity in developing countries: an assessment, Handbook of Agricultural Economics, 3, 2461–2532

ORMVAT (Regional Office of the Agricultural Development in the Tadla), 2009. Monographie du périmètre irrigué du Tadla, Fquih Ben Salah, Morocco

Pacheco, F., 2006. Dairy production systems in the Entre Douro e Minho region. Remarks about a technical support to farmers, Options Méditerranéennes Series A, 70, 179–185

Perera, B.M.A.O. 2007. A coordinated research program to develop methodologies for an integrated approach to improve small scale market oriented dairy systems in developing countries, Tropical Animal Health and Production, 39, 543–548

Robinson, P.H., Givens, D.I. and Getachew, G., 2004. Evaluation of NRC, UC Davis and ADAS approaches to estimate the metabolizable energy value of feeds at maintenance energy intake from equations utilizing chemical assays and in vitro determinations, Animal Feed Science and Technology, 114, 75–90

Sraïri, M.T. and Chohin Kuper, A., 2007. Conséquences de la libéralisation des marchés sur les opérateurs de la filière laitière au Maroc, Revue d'Élevage et de Médecine vétérinaire des Pays tropicaux, 60, pp. 177–187. Available at: http://remvt.cirad.fr/. Accessed March 29th, 2010

Sraïri, M.T., Rjafallah, H., Kuper, M. and Le Gal, P.-Y., 2009a. Water productivity through dual purpose (milk and meat) herds in the Tadla irrigation scheme, Morocco, Irrigation and Drainage, 58, S334–S345

Sraïri, M.T., Kiade, N., Lyoubi, R., Messad, S. and Faye, B., 2009b. A comparison of dairy cattle systems in an irrigated perimeter and a suburban region: case study from Morocco, Tropical Animal Health and Production, 41, 835–843

Val-Arreola, D., Kebreab, E., Mills, J.A., Wiggins, S.L. and France, J., 2004. Forage production and nutrient availability in small-scale dairy systems in central Mexico using linear programming and partial budgeting. Nutrient Cycling in Agroecosystems, 69, 191–201

Vérité, R. and Peyraud, J.L., 1988. Nutrition azotée. In: R. Jarrige (ed), Alimentation des bovins, ovins et caprins, (INRA Éditions, Paris, France), 75–93

Vermorel, M. and Coulon, J.B., 1998. Comparison of the National Research Council energy system for lactating cows with four European systems, Journal of Dairy Science, 81, 846–855

Wilmink, J.B.M., 1987. Adjustment of test-day milk, fat and protein yield for age, season and stage of lactation, Livestock Production Science, 16, 335–348