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Associations Between Nondietary Factors and Dairy Herd Performance

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ABSTRACT

Forty-seven dairy herds (approximately 3,129 lactating cows) from northeast of Spain that were offering exactly the same lactating ration were surveyed to determine the effect of nondietary factors on herd performance. The survey collected information on the profile of the owners (their future intentions, the number of workers, and time devoted to the enterprise), information regarding the animals (reproductive performance, incidence of pathology, culling rate, etc.), information on the facilities (number of feeders, waters, stalls, cleanliness, etc.) and information on management practices (numbers of daily milkings, feed deliveries, feed push-ups, cleaning frequency, etc.). In addition, the chemical quality of drinking water from each dairy enterprise was determined. Also, amount of feed delivered to each herd, daily total milk production, and milk quality were obtained for each herd for a period of 8 mo before the fulfillment of the survey. Mortality rate of calves tended to be lesser in herds that weaned progressively than in those that weaned abruptly. Age at first calving was negatively correlated with level of milk production (mainly due to the type of heifer rearing system used). Culling rate tended to be lower in herds that used a close-up ration than in those that did not. Using gloves and paper towels (instead of cloth towels) tended to reduce the somatic cell count in milk. Concentration of calcium in the drinking water tended to be negatively correlated with the number of days open and with the proportion of cows culled due to infertility problems. Despite that the 47 herds fed the same ration and shared a similar genetic base, average milk production per cow ranged from 20.6 to 33.8 kg/d. A positive relationship ($r = 0.57$) between the number of stalls per cow and milk production was found. The most important nondietary factors that affected milk production in these dairy herds were age at first calving, presence or absence of feed refusals, number of free stalls per lactating cow, and whether feed was pushed up in the feed bunk. These factors accounted for more than 50% of the observed variation, not attributable to the diet, in milk yield.
Key words: water, housing, management, performance

INTRODUCTION

Nutritional models [CNCPS (Fox et al., 1992); Dutch DVE/OEB system (Tamminga et al., 1994; NRC, 2001; INRA, 2007)] calculate nutrient requirements under the assumption that animals have ad libitum access to feed and water and are kept under dry and clean conditions. Some models incorporate correcting factors to the energy requirements for maintenance based on the environment surrounding the animals. For instance, the NRC (2001) increases by a factor of 10% the energy requirements for maintenance when animals are housed in free stalls or bedded packs as opposed to tie-stalls, and warns nutritionists that stress may exert an impact on animal requirements and some dietary adjustments might be needed in different housing conditions. Similarly, the Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al., 1992) was revised to incorporate equations that would modify nutrient requirements based on ambient temperature, humidity, and housing conditions (Fox and Tylutki, 1998).

However, herd performance is affected by several factors including nutrition, reproduction, genetics, environment, and management. Among these factors, the impact of management and environment where cows are housed is the least known. Some of these environmental factors modify herd performance indirectly by causing a reduction on the animal well-being and a subsequent increase in stress. The biological cost associated with stress may affect animal performance and health (Moberg, 2000). Also, some of the environ-

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mental factors (flooring, stocking density, etc.) affect herd performance through the modulation of lameness incidence, and there is evidence that lameness impairs milk production (Faull et al., 1996; Seegers et al., 1998; Bach et al., 2007). Some other factors, such as feedbunk space may affect animal performance through competition and stress at the feed bunk (Grant and Albright, 2001; DeVries et al., 2003). There are several studies (Jordan and Fourdraine, 1993; Spahr, 1993; Losinger and Heinrichs, 1996) that have evaluated the relationship between management and herd performance. However, the rations fed in all the herds participating in the study were different, and thus some of the result could be linked to the type of ration rather than the management practice under study. The objective of the current study was to associate several aspects of cow management directly unrelated to the diet with herd performance of 47 different dairy herds that offered exactly the same diet to their lactating cows.

Table 1. Ingredient and nutrient composition of the total mixed ration fed in 47 different dairy farms

Item	Composition
Ingredient, % of DM	
Corn silage	26.7
Triticale silage	12.9
Corn meal	11.8
Soybean meal	10.2
Alfalfa hay	7.2
Barley meal	5.6
Corn gluten feed	5.2
Beet pulp	4.5
Wheat middlings	3.2
Soybean hulls	3.1
Molasses	2.5
Rye meal	2.4
Meadow fescue hay	2.3
Sodium bicarbonate	0.8
Palm oil	0.55
Extruded soybeans	0.42
Sodium chloride	0.33
Mineral-vitamin premix	0.20
Magnesium oxide	0.13
Urea	0.13
Calcium carbonate	0.08
Nutrient	
Crude protein, % of DM	16.1
Neutral detergent fiber, % of DM	35.8
Nonfibrous carbohydrates, % of DM	40.4
Ether extract, % of DM	3.3
Net energy of lactation, Mcal/kg of DM	1.62

MATERIALS AND METHODS

Forty-seven dairy herds (about 3,129 lactating cows) from Alt Urgell in the northeast of Spain that offered exactly the same lactating ration were surveyed. There were more farms that also fed the same TMR but were not included in the survey because they offered forages or other feed supplements in addition to the common TMR. The genetic basis of these 47 herds was similar (mainly of Canadian origin). The same TMR (Table 1) that was mixed and prepared daily at the facilities of a local cooperative (Pirenaica Societat Cooperativa Catalana Limitada, La Seu d'Urgell, Spain) and distributed fresh once daily to each farm. The DM content of the TMR was determined on a daily basis. All farms were located in the same geographical area within a radius of 50 km. This area is at an altitude of about 800 m above the sea level, and the average temperatures are 4.6, 10.9, 21.4, and 11.4°C for winter, spring, summer, and fall, respectively. The average annual precipitation is about 500 mm.

The survey was conducted by 9 people that were familiar with the dairy enterprises during July and August, 2006. Milk production and milk quality records were collected daily and every 2 wk, respectively, from the milk processing plant (Cadí Societat Cooperativa Catalana Limitada, La Seu d'Urgell, Spain) starting 8 mo before the time the survey was performed. These data included total milk production, and milk protein, fat, and urea concentrations. The survey covered aspects on farm general management, calf care, heifer care, dry cow care, and lactating cow management (Table 2). Health and reproductive aspects were collected by the same people performing the survey during the 8 mo, and data regarding management and facilities were collected once. In addition, at the time of conducting the survey 2 samples of 250 mL each of water from a waterer from the lactating cows' pen were obtained and analyzed by photometry (Spectroquant Nova 60, Merck, Barcelona, Spain) to determine the concentration of ammonium (NH_4^+), calcium (Ca^{++}), total chlorine (Cl_2), chloride ions (Cl^-), hardness, nitrates (NO_3^-), nitrites (NO_2^-), and sulfates (SO_4^{2-}). Water pH was measured with a portable pH meter (Basic 20, Crison, Barcelona, Spain).

Milk production and milk quality data were averaged per each farm over the entire 8 mo considered in the study. Similarly, the amount of TMR that was delivered daily to each farm during the 8-mo period was recorded and averaged within herd and multiplied by the average DM content (51%) of the TMR fed. Also, the number of lactating cows present daily in each dairy herd was averaged over the 8-mo period. All suitable variables were tested, one at a time, in a linear regression model with milk production, milk quality, and reproductive parameters as dependent variables. After evaluating each individual independent variable, all explanatory variables with a statistical association of $P < 0.2$ were included in a model using backward elimination and milk yield as the dependent variable. Any variable significant at $P < 0.10$ was left in

Table 2. Summary of observations obtained in 47 dairy herds feeding the same lactating ration

General management	Calf care	Heifer care	Dry cow care	Lactating cow care
Number of workers	Number of animals	Number of animals	Number of animals	Number of animals
Age of owner(s)	Colostrum feeding (number of doses, volume...)	Age at first breeding	Duration of dry period	Housing system (stalls vs. bedded-pack)
Daily working hours/worker	Type and amount of milk (whole, replacer, dilution rate...)	Age at first calving	Animals per group	Number of stalls per cow
Working days/week and worker	Weaning age	Mortality rate	Mastitis treatment (is it done? how?)	Stall maintenance (cleaning frequency, general aspect of stalls)
Recent investments (new tractor, parlor...)	Weaning method (abrupt or progressive)	Fertility rate	Close-up management (is it done? when?)	Number of waterers per cow
Future plans (willingness to continue)	Forage availability (age is first offered)		Hoof trimming (how often and when?)	Feedbunk space per cow
	Water availability (age is first offered)			Waterer maintenance (cleaning frequency, general aspect of waterers)
	Mortality rate			Feedbunk management (cleaning procedure, feed refusals, feed push-ups, etc.)
	Housing method (individual vs. group)			Number of daily milkings
				Milking time, h/d
				Milking settings (vacuum level, type of parlor)
				Milking routine (gloves, paper towels, dipping...)
				Cull rate
				Cull reasons
				Fertility rate
				DIM
				DIM at first breeding
				Hoof care (how often and when)

the model. Initially, the model included the random effect of the 9 people conducting the surveys, but this factor was later removed due to lack of significance.

All statistical analyses were conducted with JMP (2007; version 7.01 for Macintosh). Descriptive statistics are presented as means with their associated standard deviation, whereas inferential results are presented as least square means with their associated standard error.

RESULTS AND DISCUSSION

The average herd size was 68 ± 39.2 (mean ± SD) lactating cows with a range from 23 to 232 lactating cows per herd. The average age of the youngest owner (some enterprises had more than one owner) of the dairy enterprises was 43.6 ± 9.83 yr (mean ± SD). The owners devoted an average of 6.5 ± 1.07 d/wk (mean ± SD) to the farm, with an average working time of 8.5 ± 3.09 h/d (mean ± SD). At the moment that the survey was conducted, 93.6% of the owners answered that they would continue their business in the future, and 44.7% had recently invested to improve their dairies.

Calves

The majority of farmers (87.2%) kept suckling calves individually housed. Calves received an average of 2.2 ± 0.74 (mean ± SD) doses of colostrum [with each dose averaging 2.2 ± 1.23 L (mean ± SD)]; thus the total average consumption of colostrum was 4.9 ± 2.38 L/calf (mean ± SD). No relationship was found between the amount of colostrum fed and the mortality rate of calves. Previous studies have not found a clear relationship between amount of colostrum fed and mortality rate (Heinrichs et al., 1987; Losinger and Heinrichs, 1996). Probably, the important aspect is the combination of time lapsed between birth and first colostrum feeding and amount of colostrum offered (Morin et al., 1997), but this aspect was not assessed in the current study. Nevertheless, the average calf mortality in the surveyed herds was not excessively high [4.7 ± 5.57% (mean ± SD)], although there were some herds with a calf mortality as high as 20%.

After offering colostrum, 57.5% of producers offered milk replacer and the remaining 42.5% offered whole milk to calves. The majority of producers offered milk or milk replacer twice daily, although a few offered it

3 times a day. The average amount of milk or milk replacer offered to calves was 2.1 ± 0.32 L/dose (mean ± SD), and the average daily total consumption was 4.4 ± 0.79 L/d (mean ± SD). The dilution rate of milk replacer was 11.2 ± 4.07% (mean ± SD). About half (42.6%) of producers weaned their calves suddenly, whereas the rest weaned progressively (some producers for 1 wk and others for 2 wk). There was a tendency ($P = 0.08$) for producers that weaned progressively to have a lower calf mortality rate (3.4 ± 1.31%) than those that weaned abruptly (6.9 ± 1.40%). Average weaning age was 80.5 ± 17.48 d (mean ± SD).

No attempt was made to determine the relationship between the parameters measured in calves during surveys and the level of milk production because this relationship would suffer from a large lag in the sense that, for example, the actual amount of colostrum that current lactating cows consumed at least 2 yr earlier could not be known and it could have been different from that currently recorded.

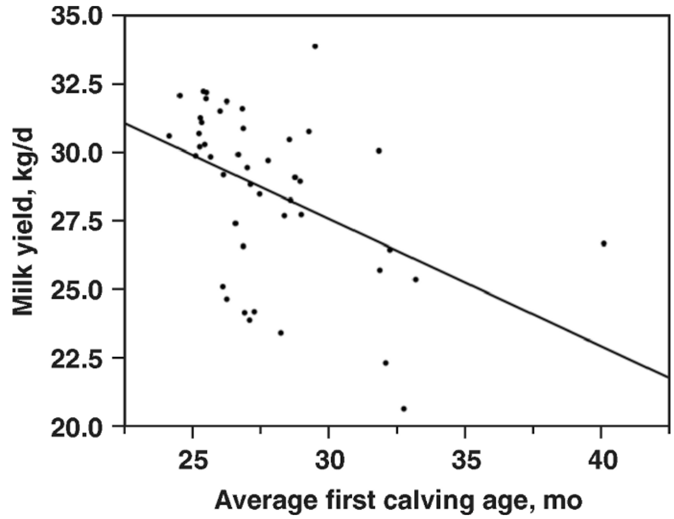

Figure 1. Relationship between age at first calving and milk production of dairy cattle in different herds (n = 47) feeding the same lactating ration.

Heifers

Heifers were first bred, on average, at the age of 16.9 ± 3.09 mo (mean ± SD). The average fertility (proportion of pregnancies relative to number of inseminations) of heifers was 61.0 ± 16.22% (mean ± SD). The combination of age at first breeding and fertility lead to an average age at first calving (**AFC**) of 27.7 ± 3.18 mo (mean ± SD). A negative relationship (r = –0.46; $P < 0.05$) was found between AFC and milk production (Figure 1). Contrarily to the case of calves, this relationship suffers from a small degree of lag because milk production was calculated using data from a relatively large proportion of cows that also contributed to the AFC values. There is evidence in the literature that indicates that AFC has little correlation with milk production during the first lactation provided that age is above 22 mo (Hoffman and Funk, 1992), although Losinger and Heinrichs (1996) reported a negative effect of AFC on future milk production when AFC was beyond 27 mo (which would support the observations from the current study). However, BW seems to have a larger effect on milk production than age. Bach and Ahedo (2008) reported a weak, but positive, relationship between calving BW at first calving and milk production during the first 150 d of lactation of 348 heifers, and Losinger and Heinrichs (1996) reported greater milk production when heifers calved with a BW above 545 kg compared with lighter heifers. In the current study, the negative relationship found between AFC and milk production could be related to the system used for rearing calves. The majority (87.2%) of herds reared heifers on pasture conditions, and perhaps this rearing system could have resulted in lighter BW than those obtained when heifers were raised under confinement where they might have achieved a greater BW at an earlier age. A positive relationship (r = 0.37; $P < 0.05$) was found between AFC and milk fat content. This was most likely due to the negative relationship between AFC and milk yield. Similarly, milk protein content tended (r = 0.37; $P = 0.07$) to increase as AFC increased.

Dry Cows

Across all surveyed dairy herds, the dry period had an average duration of 59.3 ± 5.7 d (mean ± SD). More than half (57.5%) of producers used a close-up ration to prepare cows for lactation during an average of 11.2 ± 4.07 d (mean ± SD) before the expected date of calving. There was no relationship between average milk production and the usage of a close-up ration. However, herds that used a close-up ration tended ($P = 0.06$) to have a lower culling rate (35.7 ± 2.45%) than those that did not (43.3 ± 3.08%).

About half (51%) of the herds checked and trimmed hooves during the dry period. There were no differences in milk production between herds that trimmed cows during the dry period and those that did not. However, there was a numerical tendency ($P = 0.12$) for those herds that did not trim dry cows to have a greater proportion of culled cows due to lame problems (7.4 ± 1.74% of cows culled) compared with those that trimmed cows during the dry period (3.9 ± 1.64% of

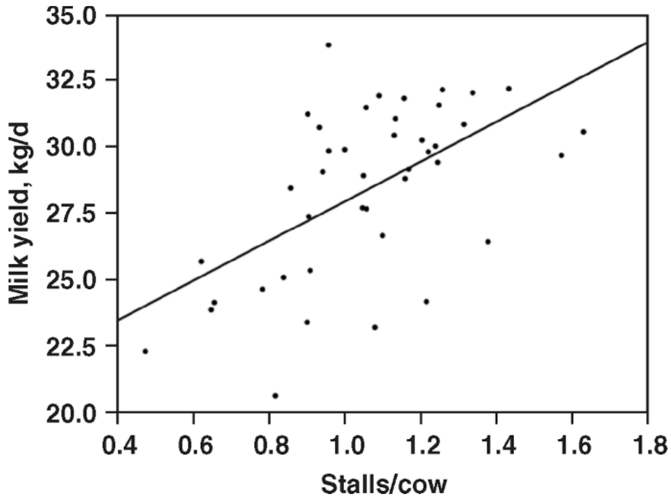

Figure 2. Relationship between the ratio of stalls per cow and milk production of dairy cattle in different herds (n = 47) feeding the same lactating ration. Milk yield = 20.4 + 7.5 × stall/cow.

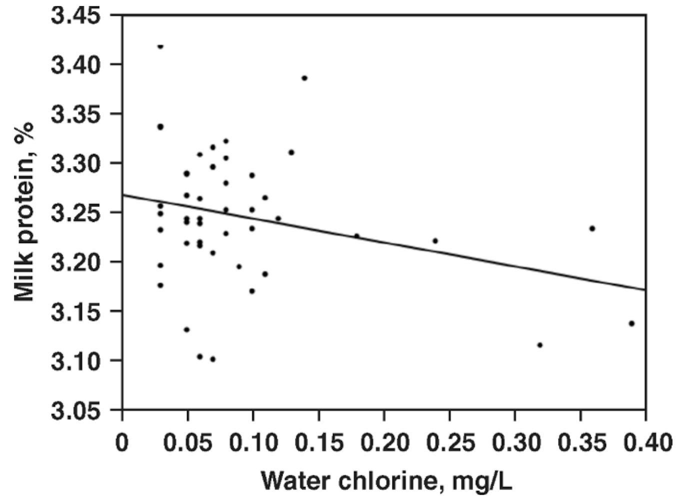

Figure 4. Relationship between water chlorine concentration in drinking water from different herds (n = 47) feeding the same lactating ration.

cows culled). These observations could agree with the report by Espejo and Endres (2007) who showed that prevalence of lameness was greater when hoof trimming was performed when the manager decided based on the conditions of the hooves compared with herds where cows were trimmed on a maintenance schedule.

Lactating Cows

It is interesting to note that despite the fact that the 47 herds offered the same ration and shared a similar genetic base, average milk production per cow within herd and day ranged from 20.6 to 33.8 kg/d (with a global average of 29.3 kg/d). This relatively large difference in milk production illustrates the importance that nondietary factors exert on determining milk performance of a herd. Despite the fact that all herds fed the same diet the amount of feed delivered per cow ranged from 16.2 to 24.8 kg of DM/d among all herds. The actual amount of feed consumed could not be known because orts were not measured. As expected, the amount of feed delivered per cow was positively correlated (r = 0.35; $P < 0.05$) with milk production. Reasons for the observed variation in intake could be, in part, attributed to the management and housing conditions of the animals. However, the ratio of free stalls to lactating animals was the only measured parameter that tended to be correlated (r = 0.26; P = 0.13) with the amount of feed delivered per cow daily.

Slightly more than half (59.6%) of the herds provided enough feed to ensure that there were some feed refusals next day. Herds that fed to ensure feed refusals tended (P = 0.09) to produce more milk (29.1 ± 0.61 kg/d) than those that did not allow feed refusals (27.5 ± 0.73 kg/d). Surprisingly, no relationship was found between the number of feeders or centimeters of feedbunk space per cow and animal performance, incidence of lameness, or culling rate. The average feed bunk space was 69 cm/animal (with less than 20% of herds with less than 50 cm of feed bunk per animal), which could be considered sufficient to avoid any limitations of feed intake and animal performance. In fact, Grant and Albright (2001) concluded that the minimum critical bunk space for dairy cattle was 20 cm/head.

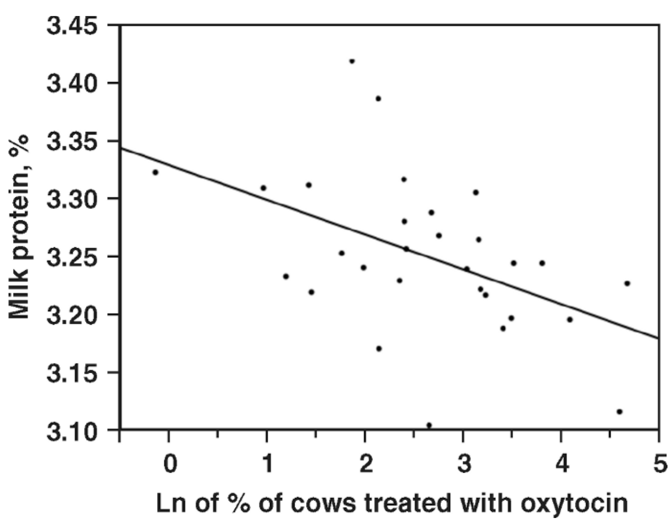

Figure 3. Relationship between the proportion of cows treated with oxytocin during milking and tank milk protein content in different herds (n = 29) feeding the same lactating ration.

Only 10.6% of the herds did not push the feed throughout the day (pushing the feed ensures that feed is within reach of cows). Producers that did push the feed performed this task 2 ± 0.67 (mean ± SD) times daily. Pushing the feed had a positive impact on milk production ($P < 0.05$). Herds that pushed up feed produced on average 28.9 kg/d, whereas those that did not produced only 25.0 kg/d. However, there was no relationship ($P = 0.67$) between the number of daily feed push-ups and milk yield. Some producers pushed the feed up to 4 times per day, whereas others just pushed feed once daily. Although some researchers have noted a slight increase in feeding activity of cows experiencing more frequent feed push-ups (Menzi and Chase, 1994), a more recent study concluded that additional daily feed push-ups did not significantly increase feeding activity when compared with a baseline schedule of 2 feedings and 2 feed push-ups/d (DeVries et al., 2003). However, there are no studies that evaluate the relationship between changes in feeding behavior associated with pushing the feed and milk production. Perhaps, the most important aspect might be to ensure that cows have feed within their reach at all times (Albright, 1993; Grant and Albright, 1995).

The majority (85.1%) of dairies kept the lactating cows on free-stalls, whereas the others housed them on bedded packs. The average number of stalls per lactating cow was 1.1 ± 0.24 (mean ± SD). A positive relationship (r = 0.57; $P < 0.05$) between the number of stalls per cow and milk production was found (Figure 2). When the regression model considered the maintenance status of the cubicle, it accounted for about 38% of the variation observed in milk production (r = 0.62; $P < 0.01$), with the stalls worst maintained resulting in the poorest performance, the intermediate stalls in the intermediate production, and the best maintained in the highest milk production per cow. In addition, a negative relationship (r = –0.39; $P < 0.05$) between the number of stalls per cow and the proportion of cows culled was found. Grant and Albright (2001) reported that significant overcrowding appears to reduce feeding activity, alter resting behavior, and decrease rumination activity. It could be speculated that the better the maintenance and the greater the availability of stalls the longer resting times of cows and thus greater milk production. Increases in stocking density have been associated with increased risk of lameness (Wierenga and Hopster, 1990) and reduced feeding times (Huzzey et al., 2006). This association could have an impact on the proportion of cows that are involuntarily culled. In any case, it is important to note that only 29% of the herds had less than 1 stall per cow. When data from herds with at least 1 stall per cow was regressed against milk production no statistically significant relationship was found (r = 0.22; $P = 0.27$). These data indicate that overstocking may have negative consequences on milk performance and understocking should have no positive impact on milk yield.

Most producers (80.9%) walked the cows through a foot-bath after milking. However, the proportion of cows culled due to lameness problems was only numerically ($P = 0.47$) lower for producers that walked their cows through a foot-bath (5.3 ± 1.37%) than for those that did not (7.7 ± 3.01%). Barker et al. (2007) have recently reported no differences in lameness incidence when comparing herds that applied foot-baths and those that did not.

In the majority of herds, cows were kept in a single group and only a few herds (19.1%) kept fresh cows separated from the rest of lactating animals. Despite the fact that fresh cows were housed in a different group, they were fed the same TMR as the rest of cows (and herds). Although there was more than 1 kg/d difference in milk production between the enterprises that created groups of fresh cows (29.7 kg/d) and those that did not (28.1 kg/d), this difference was not significant ($P = 0.21$).

All surveyed herds milked twice daily. The total number of hours devoted to milking was on average 3.1 ± 1.11 h/d (mean ± SD). The average vacuum level used during milking was 45.2 ± 2.65 kPa (mean ± SD), and no relationship was found between vacuum level and milk production nor the amount of time devoted to milk cows. Milk composition (fat and protein) was also unaffected by the vacuum level used during milking.

Fifty-five percent of producers used gloves during milking. Only numerical differences were found in milk bacterial counts between herds that used gloves (52,912 ± 25,240 UFC/mL) and those that did not (91,993 ± 29,745 UFC/mL). However, producers that used gloves tended to have lower ($P = 0.07$) SCC (204,282 ± 21,325 cells/mL) than those that did not use gloves (266,306 ± 25,133 cells/mL). This observation is in disagreement with the report by O'Reilly et al. (2006) who described an increased risk for having high SCC in herds with traditionally low SCC values when milkers wore gloves during milking, but it is in agreement with the observations from Hutton et al. (1990) who reported a tendency for a greater proportion of herds with low SCC to have milkers wear gloves during milking compared with those herds with high SCC. In the current study, because SCC was negatively correlated with milk production (r = –0.51, $P < 0.01$), producers that used gloves tended ($P = 0.06$) to produce 1 kg/d more milk than those that did not use gloves during milking. About half (44.7%) of the pro-

Table 3. Chemical composition of water samples obtained from the waterers of 47 different dairy herds of northeastern Spain

Item	Average composition	SD
Ammonium (NH_4^+), mg/L	0.47	0.393
Calcium (Ca^{++}), mg/L	70.5	37.65
Chloride (Cl_2), mg/L	0.10	0.077
Chlorine (Cl^-), mg/L	19.8	6.86
Hardness, mg/L calcium carbonate equivalent	90.5	44.51
Nitrates (NO_3^-), mg/L	5.35	4.066
Nitrites (NO_2^-), mg/L	0.16	0.132
Sulfates (SO_4^{2-}), mg/L	65.5	52.81
pH	7.15	0.477

ducers used oxytocin in some cows during milking. Surprisingly, a negative relationship (r = –0.52; $P <$ 0.001) was found between the proportion of cows (log-transformed) within a herd that were treated with oxytocin and milk protein content (Figure 3). Some studies (Nostrand et al., 1991; Ballou et al., 1993) have not found any negative effect of this hormone on milk protein or fat composition. However, Gorewit and Sagi (1984) reported a decrease in milk protein content when comparing oxytocin infusion of 0.5 or 1.0 IU with doses of 2.0 or 3.0 IU In the current study, the producers that treated cows with oxytocin used a dose of 1 IU. All producers dried the cow's teats before placing the milking units, 68.1% of them used paper towels, whereas the remaining 31.9% used cloth towels. Producers that used paper towels had lower ($P < 0.001$) SCC (202,485 ± 18,973 cells/mL) and tended ($P = 0.06$) to produce more milk (29.1 ± 0.55 kg/d) than those that used cloth towels (295,392 ± 28,233 cells/mL and 27.2 ± 0.82 kg/d, respectively).

Milk fat and protein contents averaged 3.27 ± 0.14 and 3.25 ± 0.07% (mean ± SD), respectively. Average SCC was 231,390 ± 113,130 cells/mL. Average milk urea concentration was 299 mg/L (ranging from 260 to 321 mg/L). Milk urea concentration has been correlated with dietary CP and RUP levels (Broderick and Clayton, 1997). Some studies (Carlsson et al., 1995; Eicher et al., 1999; Godden et al., 2001) have reported that stage of lactation plays an important role determining milk urea concentrations. However, Schepers and Meijer (1998) found no significant association between milk urea and stage of lactation in feeding studies that controlled for nutritional factors. In the current study, DIM was not correlated with milk urea concentration, and only the average number of lactations tended ($P = 0.12$) to be negatively correlated (r = –0.31) with milk urea concentration.

Milk protein content decreased quadratically (r = 0.42; $P < 0.05$; milk protein, % = 3.56 – 0.01 × yield – 0.001 × yield^2) as the level of milk yield increased. In addition, milk protein content tended ($P = 0.08$) to increase as the proportion of primiparous cows in the herd increased (r = 0.27; milk protein, % = 3.18 + 0.002 × percentage of primiparous).

The average number of cows per waterer in the surveyed herds was 22.8 ± 13.99 (mean ± SD). There was no relationship between the number cows per waterer and milk production nor milk composition, probably because the number of waterers available was sufficient to avoid limitations on production in all herds. The chemical quality of the water that lactating cows were drinking was, in general, very good (Table 3). The concentration of calcium (and hardness and pH) of the drinking water tended to be negatively correlated (r = –0.28; $P = 0.08$) with the number of days open and with the proportion of cows culled due to infertility problems (r = 0.30; $P = 0.07$). Stevenson et al. (1999) also reported that increased calcium supply to dairy cows improved fertility in some herds. In addition, water calcium concentration was positively correlated (r = 0.29; $P < 0.05$) with milk urea concentration (milk urea concentration = 292.7 + 0.099 × water cal-

Table 4. Regression coefficients for several nondietary factors in relation to daily average milk production (kg/d)

Term	Estimate	SE	*P*-value
Intercept	28.37	4.434	<0.01
Age at first calving, mo	–0.26	0.126	0.05
Presence of feed refusals (yes = 1, no = 0)	0.64	0.372	0.09
Number of stalls/number of cows	5.91	1.468	<0.01
Feed is pushed (yes = 1, no = 0)	1.29	0.640	0.05

cium concentration) and tended ($P = 0.10$) to be negatively correlated (r = –0.25) with milk fat content. Water chlorine concentration was negatively correlated (r = –0.28; $P < 0.05$) with milk protein content (Figure 4). This negative correlation might be a result of a potential inhibitory effect of rumen bacteria consequence of excessive chlorine concentrations because chlorine may exert an antimicrobial effect (NRC, 1980).

A predictive regression equation that accounted for the effect of AFC, presence or absence of feed refusals, ratio of number of free stalls per lactating cow, and whether feed was pushed up in the feed bunk was able to explain 56% of the observed variation in milk production (Table 4). Thus, these 4 factors could be considered the most important nondietary factors that affected milk production in the dairy herds under study. This regression equation could be further improved by accounting for an estimate of DMI in addition to the other 4 independent variables. Dry matter intake could be estimated by dividing the total kilograms of TMR delivered to each farm and correcting for the DM content of the TMR. Feed refusals could not be quantified, thus this estimate is rather poor. Nevertheless, when this estimate was used, the regression model explained 66% of the variation observed in milk production of the 47 different herds that offered the same ration.

CONCLUSIONS

Milk production is affected by several aspects. Despite the fact that the herds studied offered the same ration, there was a considerable variation in milk production (about 13 kg/d) that could only be attributed to nondietary factors. The most important reasons for this variance in milk production were found in the rearing system of heifers (illustrated as age at first calving), feed bunk management (presence of refusals and pushing the feed), and the number of free stalls available per lactating cow. These factors were able to explain about half of the observed variation in milk production that could not be attributed to nutrition.

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