# Milk offtake of cows in smallholder farms of semiarid Sahel: low yields with high value!

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***Keywords***

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***Summary***

The cow milk offtake of 300 agropastoral smallholdings was measured every fortnight over a year in semiarid Sahel, in Dantiandou district in Niger. The numbers of cows – adults, lactating and actually milked in the morning and/or evening – were systematically recorded, as well as information on grazing management, cow feed supplementation, milk consumption and processing, and sale of dairy products. In addition, the reproduction careers of the 334 cows were documented by retrospective survey. The mean daily milk offtake per cow per milking was 0.82 ± 0.45 L. It was not significantly different between morning and evening milkings, between seasons, and between farms. However, the total milk offtake per farm, whose annual average was 507 ± 362 L, varied considerably according to the season and the farm. On average, they were higher in the recently settled Fulani camps (624 ± 377 L) than in Djerma village farms (352 ± 275 L). The larger cow population in the camps (7.1 ± 5.3 vs 4.3 ± 4.0) mainly caused this difference, although their proportion of lactating cows was lower (57%) than in village herds (73%). The results showed that better management by camp agropastoralists with less frequent milkings, more frequent use of night grazing, transhumance, and regular use of feed supplementation helped improve cow fattening and reproductive performances. Despite these low milk yields, the monetary value of the milk offtake accounted for 16% of farm and off-farm incomes in camp households, and 7% in village households. Dairy products were largely consumed by the family: 78% in camps and 84% in villages.

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## ■ INTRODUCTION

Rock engravings in the Aïr and Ifoghas mounts convey evidence of cows milked in West Africa 8000 years ago (Dupuy, 2010). Yet, in present days, the milk offtake and total production in pastoral and agropastoral systems in the Sahel remain poorly documented (Nicholson, 1984; Bocoum et al., 2013) with most of the quantitative information still unpublished, confined to technical reports or academic works. These reports are often incomplete or suffering from weaknesses: the milk offtake is not always clearly distinguished from the total milk production (Ndione et al., 2014); or it is assessed at the herd level with no information on the number of adult cows, lactating cows and milked cows, as not all lactating cows are effectively milked (Coulibaly, 2008). Moreover, the milk offtake is often assessed by recall surveys (Boukary et al., 2007; Zezza et al., 2014). When it is physically measured, it is carried out on a small number of cows (Schaffer, 1994; Baoua, 1994; Rath, 1999; Coulibaly, 2008)

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and on a short period (Baoua, 1994; Sanogo, 2011). Otherwise, databases exist but the data have been collected in research stations where breeding practices are not representative of the agropastoral farming system (Achard and Chanono, 1995; Kane, 1996; Diop et al., 2009; Ndione et al., 2014). In spite of these limitations, reported yields are consistently low compared to that of dairy units in temperate regions.

However, there is a production gap in the literature between cows whose mean total daily milk yield during lactation ranges between 1 and 3 L with 0.3 to 2.0 L milk offtake, and cows whose mean total daily milk yield ranges between 3 and 12 L with 2 to 6 L milk offtake. Moreover, the duration of the lactation and the period during which cows are milked vary largely between cattle herds, affecting overall production. Several authors report the following lactation lengths for zebu cows in Sahel: 150–180 days (d) (Denis, 1971), 246 ± 129 d (Wagenaar et al., 1986), 254 ± 16 d (Anonym, 1977), 278 ± 5 d (Achard and Chanono, 1995), 295 ± 16 d (Colin de Verdière, 1995), and 350–430 d (Rath, 1999). For comparison, Agyemang et al. (1991) report 420 d for Ndama taurine cows in a subhumid area. Resumption of milk production during the wet season, which had decreased during the previous dry season, is also observed (Bonfiglioli, 1981; Wagenaar et al., 1986; Colin de Verdière, 1995). Milking can be carried out year round (Resse et al., 1992; Colin de Verdière, 1995) or seasonally (Diop et al., 2009), and is selective in most cases, i.e. not all lactating cows are milked (Okantah, 1992; Corniaux et al., 2001; Coulibaly, 2008).

The overall objective of the study was to evaluate alternative methods based on a recall survey administered to village and camp households owning cows, and to compare them to a 12-month physical monitoring and recording of the milk offtake. The results of the survey evaluation have been published (Zezza et al., 2014). This paper reports the results of the monitoring of 300 agropastoral farms sampled in the district of Dantiandou in Western Niger. The aim was to characterize the cow milk offtake, processing, consumption and sale by the farm households. A systematic comparison was made between the sedentary crop-livestock farms of Zarma villages and the camp farms of recently settled Fulani agropastoralists (Hiernaux and Turner, 2002). The two social groups share the same lands and cattle breeds (Bororo and a few Djeli) but differ in the access rights to land, the number of cattle managed and livestock breeding experience (Turner et al., 2011). The parts of milk consumed or sold fresh as sour milk and as ghee butter were assessed, and the incomes generated were compared between the two farm types and in relation with the total farm and off-farm household revenues.

The results on the cattle milk offtake, processing, consumption and sale in the district of Dantiandou in Niger were then compared to the literature on the milk offtake in pastoral and agropastoral systems in the dry tropics of West Africa, including works carried out in research stations. The objective of these comparisons was to rank the milk offtake performance of the agropastoral system of Dantiandou district with other milk offtake data collected within the region in order to develop the diagnostic and expand the domain application.

## ■ MATERIALS AND METHODS

### *Dantiandou rural district*

Dantiandou district extends over 846 square kilometers and the small town of Dantiandou is located 80 kilometers to the east of Niamey, capital of Niger. The district harbors 35,918 inhabitants (about 42/km$^2$) in 5340 households living in 45 villages, according to the 2008 census (unpubl. data). The climate is typical of that of semiarid monsoonal tropics with an average annual rainfall of 497 ± 88 mm at Banizoumbou (1990–2015) between June and October, in all 35 ± 6 rainy days, most of which because of convective storms (Panthou et al., 2014). Rainfall during the study period was contrasted with little (414.6 mm) and ill-distributed rainfall (35% of rains needed for herbage growth) in 2011, and higher than average (564.6 mm) and well-distributed rainfall (73% of rain needed for herbage growth) in 2012 (Supplementary Material [Suppl. Mat.] I). Consequently, fodder yields in fallows (612 kg.ha$^{-1}$) and rangelands (109 kg.ha$^{-1}$), as well as millet stalk (1626 kg.ha$^{-1}$) and weed (443 kg.ha$^{-1}$) yields were below average in 2011 (Hiernaux et al., 2009). In 2012, better rains resulted in higher yields in fallows (1307 kg.ha$^{-1}$) and rangelands (418 kg.ha$^{-1}$), but not in millet stalks (856 kg.ha$^{-1}$) and weeds (235 kg.ha$^{-1}$), because of repeated locust ravages on seedlings. Monthly mean minimum temperatures ranged between 15.9°C in January and 27.4°C in May, and maximum temperatures between 32.1°C in August and 40.9°C in April (Sivakumar et al., 1993).

The district entirely lies within the Iullemmeden sedimentary basin dominated by tertiary sandstones capped by a thick Eocene ferricrete (Grimaud et al., 2014) forming a plateau. The plateau had been eroded during the humid periods of the Quaternary in a web of shallow valleys that were largely infilled with sand deposits during the arid periods of that era. Soils are either very shallow on the plateau, or deep, sandy and poorly fertile in the valleys (Turner and Hiernaux, 2015). Poor soil fertility and restricted access to water in the dry season explain the long history of the low population density that only increased steadily since the 1950s (Guengant et al., 2002). The prevailing smallholder farming system is based on millet staple, with cowpea and sorrel as associated crops, and pastoral rearing of a few zebu cattle, sheep, goats, donkeys and poultry (Osbahr, 2001).

### *Crop-livestock smallholder farm sampling*

The milk offtake of cows of 300 smallholder farms was monitored over a year, from 15 April 2012 to 15 March 2013. Samples were collected from 25 of the 45 villages in Dantiandou rural district. The farm households were selected randomly from the population census provided they managed at least one lactating cow and the family head agreed with the monitoring protocol. There were four refusals among farmers contacted for the study. Rearing at least one lactating cow biased the sample in favor of camp families (57%), mostly Fulani, to the detriment of Zarma village families (43%). Both communities cohabit in the district with their particular culture and history, as well as type of dwelling either sedentary in the villages for the Zarma majority, or in familial camps a few kilometers away from the villages for the Fulani minority. Zarma families accounted for 85.6% of the population administratively registered at Dantiandou, and Fulani families accounted for 14.4%. However, a number of Fulani residents have kept their administrative registration in their village of origin, often in neighboring districts in Dallol Bosso, so that the actual population count is closer to 25% of Fulani. Indeed, the Fulani, as transhumant pastoralists, used to visit seasonally the district with their herds. They settled in camps during the 1970s, associating staple millet crop to pastoral activities (Hiernaux and Turner, 2002).

### *Monitoring the milk offtake and herd*

The milk offtake was measured in each farm once every fortnight, with morning and evening milking when applicable. At each milking, following the local practice of pouring the milk from each cow in a common pot, the total milk offtake of the herd was poured in transparent plastic pots used for measurement. The herder marked the level reached by the milk on the outer part of the pots. To assess the milk volume, the research assistant weighed (to the gram) the empty plastic pots, then filled them with water up to the mark on the pots. In the largest herds several pots were needed. In addition the research assistant updated with the herder the number of i) adult cows present in the herd, ii) lactating cows depending on three categories (< 3,

3–12, > 12 months after parturition), and iii) cows milked on that morning and that evening.

## Herding and feeding management of lactating cows

The research assistants systematically recorded the herd management and feed supplementation information upon each visit. It included the location and time recording of herd watering, and day and night grazing in the last 24 hours. Feed supplements distributed to the herd during the last 24 hours were listed and each quantity was estimated. The number of cows that benefited from feed supplementation was also noted.

## Herd demography and reproduction parameters

Information on the sex and age class composition of the cattle, sheep and goats managed by each family was collected at the end of the milk offtake monitoring in March 2013. The mean rates of the herd offtake (slaughter, sale, gift handed out) and intake (purchase, gift received), mortality (death and losses), prolificacy, and sex ratio at birth observed in village and camp herds were documented based on a recall survey carried out over five years for cattle, two for sheep and goats, on a subsample of 166 herds.

### *Cow reproduction parameters*

Cow reproduction parameters were crosschecked with a 'career recall' type of survey conducted on one cow in each herd, preferably born within the herd so that the manager knew her career well. The duration (in months) of the previous lactation, the interval between the last two calvings, the age of the cow at first calving, its current age, and the number of calvings and abortions in her career were documented in interviews for 334 cows.

### *Mean herd composition*

Demographic and reproductive variables calculated for camp and village cattle herds were used to assess the annual rates of herd growth, animal offtake and restocking with the population dynamics model DYNMOD (Lesnoff et al., 2011) assuming a demographic steady state (Table I).

## Survey on milk offtake consumption, transformation and marketing

During each fortnight visit, an interview was conducted with the persons within the family in charge of processing and managing the milk collected the previous week. The relative amounts of the milk offtake consumed fresh or processed as curd milk were recorded. Butter was also extracted during the process and the number of butterballs (about 5 g) per week was assessed. For each product (fresh milk, curd milk and butter), the relative proportions consumed within the family, given away (including the owner of the cow) or sold were recorded weekly. Dairy products were sold either daily in neighboring villages, or weekly in the rural markets of the district (Dantiandou, Wankama) or its surroundings (Niabéré, Yéda, Kouringol).

## Farm family revenues

The survey was carried out on a subsample of 268 families (156 camps and 112 villages) in March 2013 and thus concerned the previous crop harvest and the previous year's livestock and off-farm revenues (March 2012 – March 2013) according to farmers' declarations.

### *Incomes from crops*

The family incomes from crop activities were assessed based on the harvest of millet grain, the main staple crop in Dantiandou (de Rouw and Rajot, 2004) of the October 2012 harvest, and expressed in panicle bundles. The amount of grains sold and bought (all crops included) on the market since the 2012 harvest were also included. The answer to the question "How many months will the cereal stock (2012 harvest + grain purchased – sale and consumption) suffice to feed the family" was used to estimate the grain purchase for the next harvest in October 2013. Mean cereal grain values on the market year round were used to estimate yields, sales and purchased cereals as well as future purchases.

### *Incomes from livestock*

The incomes from livestock husbandry included incomes from the sale and the increase in cattle, sheep and goats, and from the sale and consumption of cow dairy products. Livestock sale and restocking were estimated by the annual rates of offtake and stock increment with DYNMOD model (Lesnoff et al., 2011), separately for camp and village farms (Table I). These rates were applied to each farm in proportion of the number of cattle, sheep and goats managed. These assessments were then valued in CFA francs (1 € = 656 CFAF) with the annual mean of local market prices for each category of livestock. The incomes from dairy products were estimated from the annual aggregates of fresh milk, sour milk, butter sales, and family consumption, with the weighed mean of the local market price for each commodity.

### *Off-farm incomes*

Other sources of incomes included off-farm activities and remittances from activities conducted by family members who emigrated either seasonally or permanently. Off-farm activities were diverse and differed at least in proportions between camp and village families.

**Table I**

Average number of females, males and adults in the cattle, sheep and goat herds of camp and village farms, and annual growth, offtake and restocking rates* per species and farm type, in semiarid Dantiandou district in Niger

| Farm type | Species | Num. females /herd | Num. males /herd | Num. adults /herd | Growth rate (%) | Offtake rate (%) | Restocking rate (%) |
|---|---|---|---|---|---|---|---|
| Camp (n = 171) | Cattle | 11.7 | 2.1 | 7.4 | 5.1 | 13.8 | 4.9 |
| | Sheep | 8.2 | 1.9 | 5.5 | 14.9 | 30.4 | 13.8 |
| | Goat | 7.6 | 1.7 | 4.7 | 15.0 | 34.5 | 14.0 |
| Village (n = 129) | Cattle | 7.3 | 3.1 | 6.0 | 0.2 | 10.9 | 4.0 |
| | Sheep | 4.2 | 1.5 | 3.1 | 3.0 | 33.3 | 2.8 |
| | Goat | 3.5 | 1.5 | 2.4 | 2.7 | 31.3 | 3.6 |

* The rates were calculated with the DYNMOD population dynamic model (Lesnoff et al., 2011) assuming a herd steady state.

Camp families were more involved in activities related to livestock management (waged herder) or trade (conveyer, trade agent). Village families were more engaged in gathering wood, straws, vegetable gardening, and transportation. Both village and camp families declared labor work (for non-governmental organizations), trade, craft and social activities. Off-farm activities and remittances were estimated (in CFAF) based on each farmer's declaration.

## ■ RESULTS

### *Livestock in village and camp farms*

The average herd size was 9.4 ± 7.7 tropical livestock units (1 TLU = 250 kg liveweight) in camps and 7.2 ± 5.0 TLU in villages with small ruminants only accounting for 14.9% and 9.7%, respectively, of the total livestock live weight. Sheep were reared in 73.7% and 76.2% of the camp and village farms, respectively, whereas goats were reared in 75.8% and 60.9% of them. In both farm types the composition of cattle herds, as well as sheep and goat flocks, was largely dominated by adult and young females, which accounted for 79.5% and 82.2% of the cattle numbers in the camps and villages, respectively. This confirmed the farmers' reproductive strategy in spite of the small size of their herds. On average across the study period, camp farms owned larger cattle herds (7.1 ± 5.3) than village farms (4.3 ± 4.0), with 3.4 ± 2.5 *versus* 1.7 ± 1.1 lactating cows per farm, respectively. Moreover, only some of the lactating females were actually milked: on average 1.9 ± 0.8 in camps *versus* 1.2 ± 0.7 in villages. Goats and ewes were not milked in villages nor in camps.

### *Milk offtake*

#### *Milking frequency*

Most of the cows were milked only once a day, either in the morning (96.7% in camps, 98.7% in villages), and/or in the evening (31.3 vs 13.9%). The seasonal variation in the number of cows milked per farm confirmed that there were twice as many cows milked in the morning than in the evening, and their numbers were always higher in the camps than in the villages (Figure 1a). The seasonal pattern of the number of cows milked was low with a slight decrease toward the end of the dry season. On the contrary, in the early wet season, the volume of the milk offtake at each milking doubled and reached a plateau slightly above one liter until October, then progressively decreased during the dry season (Figure 1b). The daily milk offtake per farm was contrasted in camp farms with a plateau above 2.5 L from August to December, and below 1.5 L from March to June (Figure 1c). In August, the daily milk offtake was lower in village farms with a maximum of about 1.5 L, and a progressive decrease with a minimum from March to June lower than 1 L.

The mean volume obtained per cow and per milking did not vary significantly between farm types, between morning and evening milking, or its position along the lactating curve. On average, it remained between 0.77 ± 0.32 L in morning milking in villages, and 0.83 ± 0.35 L in morning milking in camps. However, the frequency distribution of the volume milked either in the morning or in the evening spanned from less than 0.25 L to 3 L per cow (Figure 2). This dissymmetry was very similar between the camps and the villages for morning milking (Figure 2a), and there were slightly more frequently higher volumes in villages for the evening milking (Figure 2b). The milk offtake range per milking was in part explained by the decrease in the volume milked per cow as the number of cows milked increased, at least up to six cows milked which seldom occurred (Figure 3). Higher volumes when milked cows were fewer also contributed to explain the higher offtake in the evening in villages compared to camps (Figure 2b).

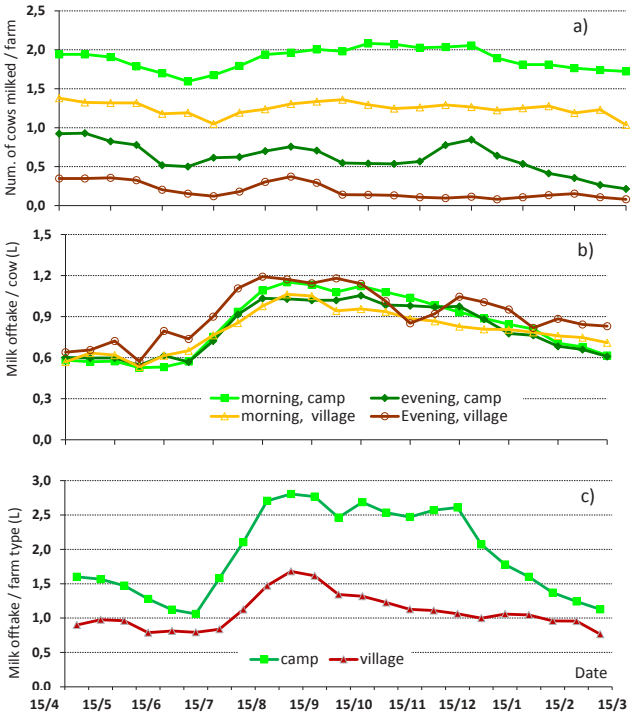


***Figure 1:*** *Daily milk offtake per fortnight from mid-April 2012 to mid-March 2013 in semiarid Dantiandou district in Niger: a) mean number of cows milked in the morning or the evening in camp or village farms, b) mean milk offtake per cow in the morning or the evening in camp or village farms, c) resulting mean daily milk offtake per either camp or village farm.*

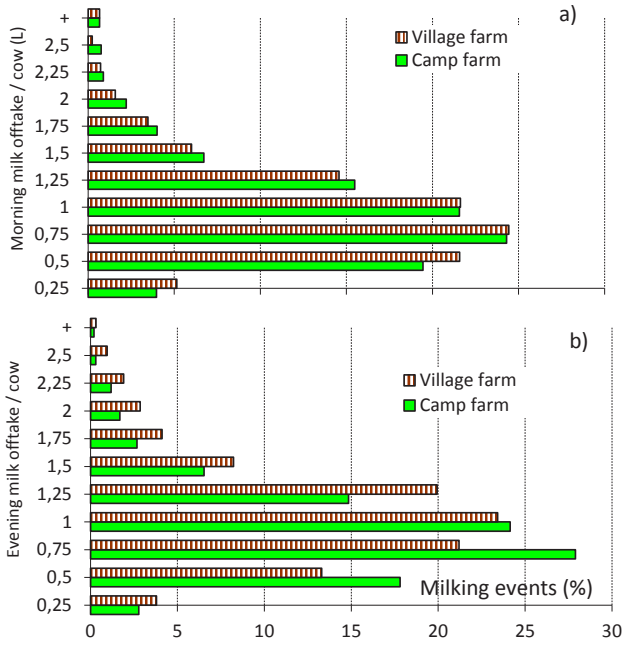


***Figure 2:*** *In semiarid Dantiandou district in Niger, distribution across farms of a) the milk offtake per cow at morning milking, b) the milk offtake per cow at evening milking.*

#### *Daily milk offtake*

Aggregating morning and evening milking, the mean milk offtake per milking day and per farm was 1.05 ± 0.44 L in camps and 0.83 ± 0.45 L in villages because of the larger number of cows milked and the more frequent milking (twice a day). Actually, the mean daily

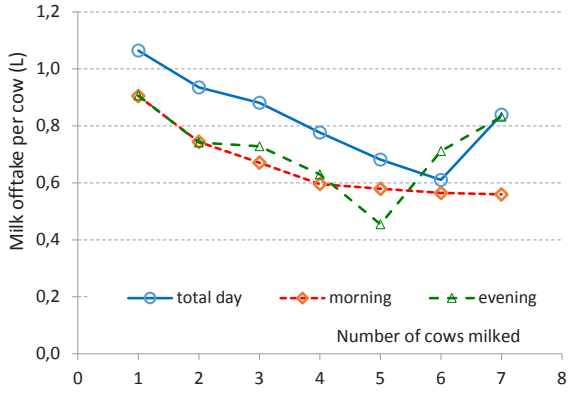


***Figure 3:*** *Mean milk offtake per cow milking as a function of the number of cows milked in the herd, in the morning, the evening and for aggregated morning and evening in semiarid Dantiandou district in Niger.*

offtake spanned widely within both farm types, from less than 0.5 L to 3.5 L in villages and up to 5 L in camps, following dissymmetric distributions (Figure 4a), with only 12% of villages and 37% of camps milking more than two liters per milking day.

***Annual milk offtake***

When the daily milk offtakes per farm were aggregated over the year the gap between villages and camps widened (Figure 4c) because of the longer milking seasons in camps (Figure 4b). For example, 44.4% of camps and only 33.3% of villages milked cows all year round. The reasons for not milking a cow on a particular day differed between camps and villages. In camps herd transhumance occurred in 7.4% of our annual monitoring, whereas entrustment to another herder occurred in 5.3% of the villages (Suppl. Mat. II). On the other hand, all the other reasons, which related to the cow weakness, drying up, diseases or social constraints, were much more prevalent in villages (17.9%) than in camps (7.5%). The average annual milk offtake per farm was 624 ± 377 L in camps and 352 ± 275 L in villages, with distinct distributions across farms, i.e. 47% of the camp offtake was between 400 and 800 L, whereas 69% the village offtake was less than 400 L (Figure 4c). The annual milk offtake per farm related linearly to the average number of cows milked during the year with a steeper slope in camp farms (Suppl. Mat. III).

## *Milking management*

The mean number of adult cows remained close to 7.2 ± 0.11 in camps and 4.4 ± 0.15 in villages throughout the year. However, in camps the proportion of lactating cows among adult cows increased markedly from less than 40% at the end of the 2012 dry season to more than 55% during the wet season, and this level was maintained during the 2013 dry season. In villages the proportion of lactating cows remained close to 40% of adult cows throughout the survey (Figure 5a). The ratio of milked to lactating cows started close to 80% in both farm types in April 2012, late in a harsh dry season. In camps it decreased toward the end of the dry season, then remained at around 50% afterwards, whereas it decreased only to 60% in camps and fluctuated between 70% and 80% afterwards (Figure 5a). On average over a large number of herds, the ratio of lactating to total adult cows decreased with the herd size, more steeply in village herds (Figure 6). The ratio of milked to lactating cows also decreased with the herd size in camps, whereas it remained high between 60% and 80% in villages. Camp and village cattle herds also differed in their composition of lactating cows as a function of time after calving, i.e. cows in early (< 3 months), mid (3–12 months), or late (> 12 months) lactation. The seasonal dynamics were strong in camps with a marked increase

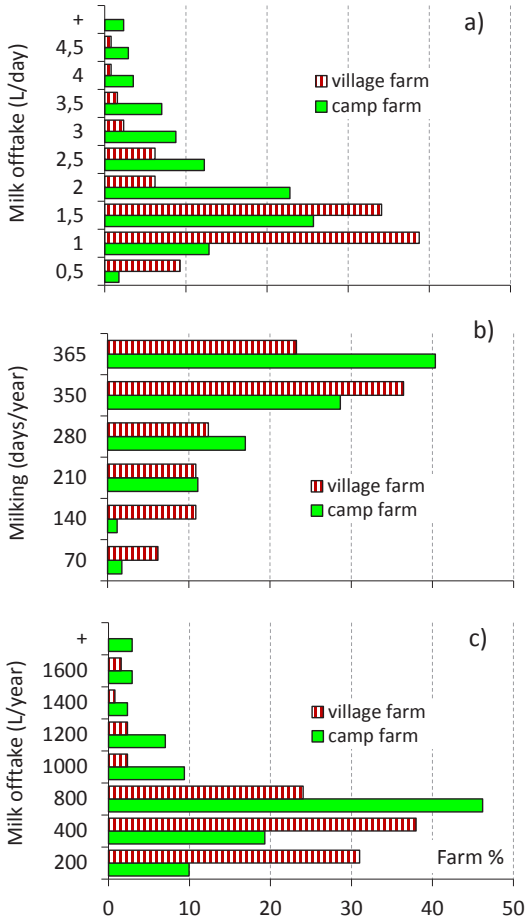


***Figure 4:*** *Aggregated milk offtake over the year in camp and village farms in semiarid Dantiandou district in Niger. Farm distribution by classes of: a) daily milk offtake per farm, b) duration of the milking period during the year, c) annual milk offtake per farm.*

of early lactation in the wet season (Figure 5b) consistent with the concentration of calvings by the end of the dry season. There was a mild increase in early lactation during the wet season in villages, which was otherwise stable.

## *Grazing management and feed supplementation*

The herds grazed during daytime for long hours (9–11 h). In addition, 73% of camp and 47% of village herds also grazed (2.3 ± 1.0 h) at night. The herds shared the same grazing lands, i.e. fallows and poorly productive rangelands during the cropping season, and open to cropland after grain harvest. Most lactating cows were supplemented 80% of the time in camps and 65% of the time in villages. In villages the cows were less frequently (down to 40%) supplemented from July to December, whereas in most camps (75%) the cows remained supplemented during the wet season. Average amounts of feed supplements distributed per cow daily were 0.8 kg in both camps and villages, varying between 0.5 kg in the wet-cool season and 1 kg in the late dry season. A range of feed supplements were distributed, mostly cereal brans, among which 53.4% in camps and 34.7% in villages were bought on the market and imported (wheat bran, cottonseeds).

## *Cow reproduction*

The sample of 334 cows selected for the reproduction career survey was characterized by a mean age of 10.4 ± 3.1 years (ranging from 4 to 19), an age at first calving of 61.8 ± 12.85 months and an average of

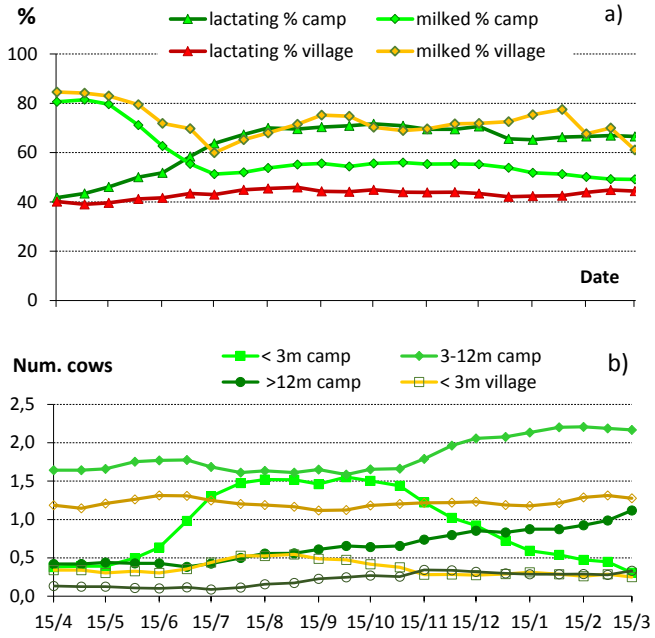


***Figure 5:*** *Seasonal dynamics of cow dairy herd means for 171 camp and 129 village farms in semiarid Dantiandou district in Niger; a) ratios of the number of lactating to total adult cows, and ratio of milked to lactating cows; b) number of lactating cows according to their ages (m = months) after calving.*

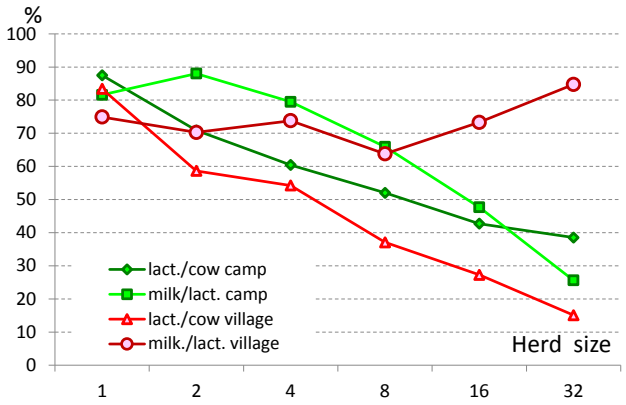


***Figure 6:*** *Annual means of the ratio between the number of lactating to total adult cows, and the ratio of milked to lactating cows as functions of the cattle herd size in camp and village dairy herds, in semiarid Dantiandou district in Niger.*

3.0 ± 1.4 calvings (ranging from 1 to 9). The prevalence of a low number of parturitions despite a spread in the age distribution was partly explained by the large age range at first calving, which usually topped at 4–5 years but could reach 8 years and more. This contributed to the mediocre regression coefficient ($r^2 = 0.55$) of the linear regression between the number of parturitions and the cow age (Suppl. Mat. IV). From the regression the mean age at first calving was 4.5 years and the interval between consecutive calvings was 35.3 months. The regressions calculated separately for camps and villages were not significantly different.

## *Milk processing, consumption and selling*

The farm family, i.e. 78% in camps and 84% in villages, consumed a large part of the milk offtake. The part consumed as fresh milk was only 11% in camps and 5% in villages. Indeed most of the milk was transformed into curd milk and butter and the quantity transformed increased during the late dry season in both farm types. The families consumed 95% of the butter extracted from milk in village farms *versus* 75% in camp farms. Thus 25% of the butter and 22% of the curd milk produced in camps were sold and mostly by camp farm women. About half of the dairy products were sold nearly daily in the largest village nearby (within five kilometers); the other half was weekly sold in market places. Depending on the location of the camp, the main markets were Dantiandou, Wankama, Niabéré, Jeda and Kouringol, all within 5–20 kilometers from the camps. The women walked to the markets carrying the dairy products on their heads. In spite of the relative proximity of the large urban market of Niamey and relay dairies at Kollo and Hamdallaye, all 45 kilometers away from Dantiandou, there was no milk collection (using plastic cans and motorbikes) on the farms, but collectors sold back to the dairies a small part of the milk sold on the markets.

## *Contribution of dairy products to farm revenues*

The average monetary value of the 2012 millet harvest was around 350,000 CFAF in villages and 200,000 CFAF in camps. Small parts of the grains were sold on the market but farmers also bought grains to meet family consumption (Table II). In spite of the larger yields and lower sales, village farmers purchased during the dry season three times more grain than camp farmers did.

### *Income from meat*

The meat component of livestock production consisted in selling animals and restocking the cattle herd and the small ruminant flocks. The monetary value of animal sales was very high compared to restocking because of the relatively high offtake rates (Table I). The average value of animal sales in camps was about twice that of villages for both cattle and small ruminants (Table II).

### *Dairy products incomes*

The mean annual incomes from the sale of dairy products (curd milk and butter) were also higher in camps although it varied a lot among farms (Suppl. Mat. V), whereas almost half of the village farms did not sell dairy products. The monetary value of the dairy products consumed within the family was also higher in camp farms but with a similar distribution shape in camp and village farms. In both farm types, the value of the consumption by the family was twice that of the sale of dairy products.

### *Supplement feed cost*

The mean cost of feed supplements distributed to the lactating cows was estimated at 75–162 CFAF per cow per day of supplementation, which aggregated over the year at 80,000–120,000 CFAF per farm. These estimates included the monetary value of the feed produced on farm such as millet bran. The daily expenses in feed supplement bought on the market was estimated per cow at 162 CFAF in camps and 76 CFAF in villages, and aggregated annually to 59,342 CFAF per camp and 27,640 CFAF per village. On average over the year the feed supplements bought on the market thus cost about 46% of the value of milk production in each farm type.

### *Off-farm incomes*

Only 58% of the camp families had some off-farm activities *versus* 92% of village families, among which 81% had at least one member involved in seasonal or long-term emigration. Seasonal emigration only concerned 38% of camp families of which only 31% declared a local off-farm activity. The mean financial incomes from off-farm activities and activities carried out during emigration were markedly higher in villages than in camps (Table II). On average only in families practicing at least one off-farm activity the annual declared revenue was about 350,000 CFAF in villages and only about 160,000 CFAF in camps. Similarly, mean annual remittances from emigration averaged

**Table II**

Monetary value (mean and standard deviation) per farm of the stock and flux of the activities of camp and village farms over a year (2012–2013) in semiarid Dantiandou district in Niger

| Economic activity | Stock and flux | Monetary value (CFAF) | | | |
|---|---|---|---|---|---|
| | | Camp farm (n = 156) | | Village farm (n = 112) | |
| | | Mean | SD | Mean | SD |
| Crop millet | Grain yield (2012) | 195,244 | 146,172 | 350,441 | 310,371 |
| | Sale | 30,311 | 43,024 | 25,848 | 70,533 |
| | Purchase | 123,992 | 80,421 | 248,405 | 207,858 |
| Cattle (meat) | Sale | 276,114 | 234,667 | 138,822 | 127,531 |
| | Restocking | 85,754 | 72,881 | 56,160 | 48,903 |
| Sheep and goats (meat) | Sale | 127,394 | 148,800 | 66,982 | 74,837 |
| | Restocking | 47,095 | 54,552 | 5,200 | 5,890 |
| Cow (dairy) | Sale | 52,841 | 52,841 | 17,950 | 32,531 |
| | Family consumption | 110,479 | 54,623 | 68,996 | 50,312 |
| | Feed purchase | 59,343 | 57,757 | 27,641 | 26,718 |
| Off-farm revenues | Local off-farm activities | 50,087 | 124,452 | 143,062 | 341,969 |
| | Migration remittances | 76,155 | 171,052 | 431,473 | 510,889 |

* The rates were calculated with the DYNMOD population dynamic model (Lesnoff et al., 2011) assuming a herd steady state.

420,000 CFAF in involved villages and only 86,000 CFAF in camps. This disparity in incomes from off-farm activities between the two farm types explained why the total annual income of village families was less bound to the livestock capital than that of camp families (Suppl. Mat. V).

## ■ DISCUSSION

The milk offtake of zebu cows measured over a year from mid-April 2012 to mid-March 2013 in 300 agropastoral farms in the Dantiandou district of Western Niger ranks among the lowest in Sahel according to the literature (Coulomb et al., 1980; Nicholson, 1984; Wagenaar et al., 1986; Sanogo, 2011). Yet the fodder available during the study period was representative of the local conditions. Its supply was low during the first three months, i.e. the late dry season following a poor rainy season (2011), but it became better than average during and after the abundant 2012 rainfall, even if locusts ravaged part of the millet stalks. Even when the milk offtake was reported only to milked cows during the milking season, the daily mean offtake was 1.05 ± 0.44 L in camp farms and 0.83 ± 0.45 L in village farms. This is far below the two liters threshold that separates poor production (Wagenaar et al., 1986; Agyemang et al., 1991; Colin de Verdière, 1995; Baoua, 1994; Ezanno et al., 2005; Coulibaly, 2008; Sanogo, 2011) from satisfactory production (Anonyme, 1977; Achard et Chanono, 1995; Rath, 1999; Vias et al., 2003; Ndione et al., 2014), generally reported in Sahel pastoral and agropastoral systems. The two liters a day threshold was only surpassed in 15% of the 6900 daily measures performed during the project.

These low performances are in line with the controversial reputation of the largely dominant Bororo breed as a milk producer (Thébaud, 1999; Krätli, 2009). Indeed, the dairy performance is often supposed to depend on the species and breed of the cow – taurine, zebu or their crosses –, and the African zebu performs better than the trypanotolerant taurine species. Fine dairy breeds in the region include Gobra in Senegal (Ndione et al., 2014), Moorish zebu in Mali (Anonym, 1977), Azawak in Niger (Achard and Chanono, 1995), White Fulani in Nigeria (Rege et al., 1993), whereas poor dairy breeds include Djeli and Bororo in Niger, Nigeria and Chad (Krätli, 2009), Macina Fulani (Wagenaar et al., 1986), and Gudali in Nigeria (Blench, 1999). Similarly with taurine species, the Kuri cow has a higher reputation for dairy (Blench, 1999) than the N'dama cow of the subhumid zone (Agyemang et al., 1991; Ezanno et al., 2005), which has in turn a better reputation than the West African Shorthorns (Baoulé, Somba, Kapsiki).

However, the results show that poor nutrition in the dry season impedes the cows to reproduce and produce milk up to their genetic potential as already observed in Sahel (Kane, 1996; Rath, 1999; Coulibaly, 2008; Vias et al., 2003). The high seasonal milk offtake effect observed in all herds, as the milk offtake doubled at the onset of the wet season and gradually decreased during the long dry season, reflects the seasonal nutritional constraint on milk production reported in most Sahel livestock production systems (Wagenaar et al., 1986; Colin de Verdière, 1995; Rath, 1999; Diop et al., 2009). The severity of the feed constraint was confirmed by the high proportion (4.4% in camp herds, 10.9% in village herds) of milking interruption explained by the weakness of the cow or her calf, or by the cow 'refusal' to release milk as reported by the herder (Suppl. Mat. II). The same nutritional constraint partly explained the high frequency of transhumance out of the district (7.4% of camp herds). Transhumance occurs during the wet season when the livestock is not allowed in croplands, but also in the early dry season to take better advantage of millet crop residues accessible for grazing in neighboring Dallol Bosso, and finally in the late dry season searching for remaining forages further south (Turner et al., 2011).

Chronic undernutrition occured despite cows grazing at least nine hours during the day and also at night, at least during the dry season

for 73% of the camp and 47% of the village herds. The matter is both the quality and quantity of available grazing resources (Fernandez-Rivera et al., 2005). The bulk of the herbaceous layer of fallows and rangelands was made of unpalatable dicotyledons such as *Mitracarpus scaber* and *Sida cordifolia*, and poorly palatable grasses such *as Schizachyrium exile* and *Ctenium elegans* (Hiernaux et al., 2009). The better quality grasses such as *Cenchrus biflorus* and *Brachiaria xantholeuca*, and legumes such as *Zornia glochidiata* and *Alysicarpus ovalifolius* were quickly grazed down, unless they were harvested to be sold as fodder to urban livestock keepers, an increasing practice around Niamey. Moreover, almost all lactating cows were supplemented daily with good nutritive quality feeds dominated by cereal brans. However, the mean amount of supplements was limited to 0.8 $kg.d^{-1}$ per cow. By lack of quantification of the grazing intake, we could not analyze fully the links between cow nutrition and milk offtake. However, the larger and more continuous feed supplementation of the camp cows than that of village cows could have contributed to a higher milk offtake and confirmed the determinant role of cow nutrition in milk production, as reported in feeding trials conducted in controlled conditions with various cattle breeds (Anonym, 1977; Reese et al., 1992; Sanogo et al., 2010; Ndione et al., 2014).

The larger milk offtake in camp farms than in village farms was not explained by the offtake at each milking, which was actually slightly larger in village farms, and it was only marginally explained by the more frequent twice-a-day milking in camps. Actually, the milk yield was mostly determined by the number of cows milked and the duration of the milking period over the year. The number of cows milked is constrained by the number of lactating cows in the herd but it is also determined by the herder's decision to milk a cow or to leave the whole milk to the calf (Corniaux et al., 2006). The ratio of the number of cows milked to cows in lactation decreased markedly with the size of the herd in the camps, whereas it remained above 60% in villages regardless of the herd size. In addition, the volume milked per cow tended to decrease with the number of cows milked within a farm. Altogether, the milking rate was higher in villages, wich had a smaller number of cows than camps had.

Sparing lactating cows from milking to leave the whole milk to the calves was a common practice of camp herders, at least when they managed more than three lactating cows. The higher competition of the milk offtake with calf nutrition in village herds could have contributed to affect the reproduction parameters of the cows, placing the village herds at the edge of viability for population maintenance (Lesnoff et al., 2012). This type of cow management could also explain the lower proportion of lactating cows among the adult cows observed in villages than in camps, notwithstanding in both farm types the relative number of lactating cows decreased with the size of the herd. In addition to lower milk offtake rates, the grazing management of cattle herds that involved higher seasonal mobility, more frequent night grazing, and larger and more continuous feed supplementation could also have contributed to better reproduction parameters in camp cows. Herd management could also explain the more seasonal pattern of the milk offtake in camp farms, guided by the concentration of calvings toward the end of the dry season, as revealed by the increase in new lactating cows (< 3 months of lactation) milked at the onset of rains, from mid-June to early August.

It is generally admitted that African zebu breeds require the presence and suckling of their calf to release milk. Thereafter, milk production is reported to die out soon after cows loose their calves, and the adoption by the cow of another calf is uncommon and requires devoted treatments (Bonfiglioli, 1981). Moreover, milked zebu cows are known to retain milk so that they can never be fully milked by hand (Coulibaly, 2008). No attempt was made in this survey to assess the milk suckled by the calf, and thus milk production (i.e. milk offtake plus milk suckled by the calf). The milk suckled has sometimes been assessed by weighing the calf before and after suckling (Rath, 1999), or from the calf growth by using a conversion coefficient that evolves with calf growth (Agyemang et al., 1993).

The rate of milk exploitation (i.e. the ratio of the milk offtake over milk production) is reported to vary during the lactation: the cows are generally not milked the first two weeks after calving in order to leave the colostrum to the calves. Then milking competes with suckling for six months or so, and finally as the calf increasingly grazes, a larger portion of milk production is milked. On average, authors report rates of milk exploitation of 21%–29% (Wagenaar et al., 1986) and 49%–66% (Rath, 1999) in pastoral systems, 50% (Anonym, 1977) in research station, and 57%–68% (Reese et al., 1992) in suburban dairy farms. The rate of milk exploitation in the study most probably ranked among the lowest of these values as only a fraction of lactating cows were effectively milked, and as the mean volume of milk per cow milking did not seem to vary between farm types, morning and evening milking, or depending on its position on the lactating curve.

The part of the dairy products consumed by pastoralist or agropastoralist families is seldom assessed on a large family sample and across seasons and years (Randolph et al., 2007; Bocoum et al., 2013). The few available data suggest high autoconsumption rates, especially for raw and curd milk, to a lesser extent for ghee butter and cheese (54% of offtake according to Schaffer, 1994). The portion of the milk offtake consumed by the farmers' families throughout the year was particularly high in the present study at 78% in camps and 84% in villages, mostly as curd milk and butter.

In spite of the low milk offtake and large autoconsumption, the sale of small volumes of dairy products (Wane et al., 2010) is reported to contribute notably to family revenues (Diop et al., 2009; Pica-Ciamarra et al., 2011). In the present study the monetary value of the milk offtake represented 16% of the agricultural production and off-farm incomes of the camps, and 7% of that of villages. Apart from a comparable contribution of millet yields (19% in camps vs 27% in villages), the revenue portfolios were strikingly different between the two farm types, firstly with a dominant animal production including milk in camps (70% vs only 28% in villages). Secondly, off-farm and emigration, on the contrary, only represented 12% of camp incomes *versus* 45% of village incomes. In spite of these sharp differences, the aggregate revenues from agricultural production and off-farm activities, including emigration remittances, were linearly related to the family livestock capital. As expected the regression was tighter for camps ($r^2 = 0.71$) than for villages ($r^2 = 0.37$). This relationship with the livestock capital appears much stronger than the relationship between the total farm income and family manpower, with a very poor correlation in camps ($r^2 = 0.08$) as well as in villages ($r^2 = 0.11$) (data not shown). This economic value was reinforced by the social value attached to gender specialization: processing and marketing dairy products are traditionally performed by women who manage their revenue (Dicko et al., 2006). The changes in the trade system with the development of suburban dairies and larger implication of men (Corniaux et al., 2014) remain in infancy in Dantiandou district, in spite of the relative proximity of Niamey (70 km), and recently settled collection dairies at Hamdallaye (30 km) and Kollo (45 km).

The farm family, 68% in camps and 79% in villages, consumed a large part of the monetary value of the dairy products. These high proportions highlight that the main target of the milk offtake in this region is to improve family nutrition, in contrast with suburban dairy systems, which are more market oriented with 68% milk sold in suburban Niamey (Vias et al., 2003). The small share sold on the market still represented 16% (in camps) and 7% (in villages) of the agricultural production sold by the farms, which was largely dominated by livestock sale in both farm types. When off-farm incomes were included with grain and livestock sale incomes, the sold dairy

products still made 9% of the revenues in camps, but only 2% in villages, which economy largely depended on off-farm incomes (18%) and remittances from emigration (52%).

## ■ CONCLUSION

The milk offtake of agropastoral smallholder farms in Southwestern Niger ranks among the least productive in tropical West Africa, at least in relation with the daily offtake by lactating cows. A closer analysis of the year-round monitoring data of the milk offtake in 300 farms highlights differences in production between two cohabiting farm types. The annual milk offtake was higher in the camp farms of recently settled Fulani families (624 ± 377 kg) than in the village farms of Zarma (352 ± 275 kg), milking was less frequent in camps to leave more milk to the calves. However, the offtake per milking was similar, and the milking frequency was lesser in camps, who left more milk to the calves. The main reason for the higher milk offtake in camps was the larger size of the herd (7.1 ± 5.3 vs 4.3 ± 4.0). Moreover, because the rate of exploitation of the cows was lesser, they tended to have better reproduction parameters. This led to a higher proportion of lactating females in the herd, which enabled to reduce milking frequency. However, the larger herd size was not the only reason for the better performance of camps. Better cow feeding by providing more frequently night grazing in addition to day grazing (73% vs 47%), larger regional mobility of the herds, and more regular feed supplementation (80% vs 65% days) contributed to enhance cow condition and thus reproduction parameters that were at the edge of viability in village cattle herds (Hiernaux et al., 2015). The analysis of the milk offtake performance of 300 farms in Southwestern Niger revealed a discrepancy between the livestock production of two cohabiting agropastoral systems. Although both farm types had a common environment and similar milking techniques, the livestock production of camp farms remained reproduction oriented in spite of very modest herd sizes, whereas livestock husbandry in village farms was opportunistic. In both farm types, the dairy products were mainly autoconsumed (78% in camps, 84% in villages). However, the relative share of family income, off-farm included, was substantial in camps (9%), whereas it was minimal in villages (2%).

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## *Résumé*

**Hiernaux P., Adamou K., Zezza A., Ayantunde A.A., Federighi G.** Lait de vache trait dans les petites exploitations familiales du Sahel semi-aride : des rendements faibles mais de grande valeur !

Les volumes de lait de vache traits ont été mesurés tous les quinze jours sur une année chez 300 petits exploitants agropastoraux de la zone semi-aride du Sahel, dans la commune de Dantiandou au Niger. Les effectifs de vaches – adultes, en lactation et effectivement traites le matin et/ou le soir – ont été systématiquement enregistrés, ainsi que des informations sur la gestion de la pâture, la supplémentation alimentaire des vaches, et la consommation, la transformation du lait et la vente des produits laitiers. En outre, les carrières de reproduction des 334 vaches ont été documentées par enquête rétrospective. Le volume moyen par jour d'une traite a été de 0,82 ± 0,45 L. Il n'a pas été significativement différent entre la traite du matin et celle du soir, ni entre les saisons, ni entre les élevages. Cependant, les volumes totaux de lait trait par élevage, dont la moyenne annuelle a été de 507 ± 362 L, ont fortement varié en fonction des saisons et des élevages. En moyenne, ils ont été plus élevés dans les élevages des campements peuls récemment sédentarisés (624 ± 377 L) que dans ceux des élevages villageois djerma (352 ± 275 L). Cet écart était principalement dû à un effectif de vaches plus important dans les campements (7,1 ± 5,3 vs 4,3 ± 4,0), bien que la proportion de vaches en lactation y ait été plus faible (57 %) que dans les troupeaux villageois (73 %). Les résultats ont montré qu'une meilleure gestion par les agroéleveurs des campements avec des traites moins fréquentes, un recours plus fréquent à la pâture de nuit, à la transhumance et à une supplémentation alimentaire régulière ont contribué à améliorer l'état d'engraissement des vaches et leurs performances reproductives. Malgré ces rendements laitiers modestes, la valeur monétaire du lait trait a représenté 16 % des revenus agricoles et non-agricoles des ménages des campements, et 7 % de ceux des villages. Les produits laitiers étaient largement consacrés à la consommation familiale : 78 % dans les campements et 84 % dans les villages.


***Mots-clés :*** bovin, produit laitier, traite, revenu de l'exploitation, système agropastoral, Sahel, Niger


## *Resumen*

**Hiernaux P., Adamou K., Zezza A., Ayantunde A.A., Federighi G.** Leche de vaca ordeñada en pequeñas granjas familiares de la región semiárida del Sahel: bajos rendimientos pero de alto valor!

Durante un año, se midieron cada dos semanas, los volúmenes de leche de vacas ordeñadas, en 300 pequeños productores agropastoriles en la región semiárida del Sahel, en el distrito de Dantiandou en Níger. El número de las vacas adultas, en lactación, y realmente ordeñadas por la mañana y / o noche fueron sistemáticamente registrados. También lo fueron la información sobre la gestión pastoral, la alimentación suplementaria de las vacas, el consumo y el procesamiento de la leche, así como las ventas de productos lácteos. Además, la vida reproductiva de 334 vacas fue documentada por encuesta retrospectiva. El volumen medio del ordeño fue de 0,82 ± 0,45 L. No es significativamente diferente entre el ordeño de la mañana y de la tarde, tampoco entre temporadas o granjas. Sin embargo, el volumen total de la leche ordeñada por granja cuyo promedio anual es de 507 ± 362 L, varió ampliamente dependiendo de la temporada y de la granja. En promedio, son más altos en los asentamientos recientemente establecidos de los Fulani (624 ± 377 L) que los de las granjas del pueblo de los Zarma (352 ± 275 L). Esto se debe principalmente al número de vacas más alto en los asentamientos (7,1 ± 5,3 frente a 4,3 ± 4,0), aunque la proporción de vacas en lactancia será más baja (57%) que en los rebaños del pueblo (73%). Los resultados indican que una mejor gestión en los asentamientos con ordeños menos frecuentes, pastos de noche más frecuentes, trashumancia y suplementación alimentaria más regular ayudan a mejorar la condición corporal de las vacas y su rendimiento reproductivo. A pesar de estas modestas producciones de leche, el valor monetario de la leche ordeñada representa el 16% de los ingresos, que sean agrícolas o no, de las familias que viven en los asentamientos y solo el 7% por las familias que viven en pueblos. Los productos lácteos son dedicados en gran parte al consumo familiar, el 78% en los asentamientos y el 84% en los pueblos.


***Palabras clave:*** ganado bovino, producto lácteo, ordeño, renta de la explotación, sistema agropascícola, Sahel, Níger