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Characterization of Available Feed Resources and Farmers' Feeding Practices to Improve Milk Production in Senegal

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Abstract: Livestock are an important asset in Senegal as they help improve the nutritional status of farmers and contribute to the country's economic growth. However, livestock productivity is greatly affected by climate change which affects the availability of animal feed resources. Another issue affecting livestock productivity at the farmer level is inadequate information and knowledge of the best feeding strategies. This study aimed to identify locally available animal feed resources and famers' feeding practices to improve milk production in the regions of Kaolack and Kolda in Senegal. Data were collected through the use of a structured direct questionnaire. The study revealed that natural pasture and crop residues were the main livestock feed resources. All the farmers practiced supplementation during the dry season. However, the supplementation was conducted in a haphazard manner without any measurement consideration. The main problems facing farmers in accessing supplements were limited resources, non-availability of the supplement at the local market and the high price of the supplement.

Key words: Feed resources, feeding strategies, supplementation, typology, Senegal

INTRODUCTION

In Senegal, livestock play an important role in the economy and particularly in smallholder livelihood. The rapid population growth associated with a quasi-permanent drought has led to an increase in demand for various livestock products such as milk (Somda *et al*., 2004). This has led to an increase in the number of livestock owners. In Senegal, nine out of ten households are involved in livestock farming (Habimana *et al*., 2014). However, despite the increase in livestock ownership and numbers, livestock productivity has remained low, resulting in an increased gap between the supply and demand of livestock products. According to Habimana *et al*. (2014), insufficient milk production has led to overreliance on imports which represent more than half of the milk supply. Faced with this challenge, the government of Senegal has deployed several strategies through various projects aimed to promote local milk production through actions such as the introduction of exotic dairy breeds and genetically improving local cattle breeds through artificial insemination. Although, these strategies have resulted in a significant increase in the level of milk production, there is still a gap between supply and demand.

A number of studies have shown that animal nutrition remains the most critical constraint to increasing animal productivity, especially milk production (Sauvant, 2005). Hence, the Senegalese government has embarked on processes of promoting the livestock feeding systems and management to "optimize animal productivity from local resources". The elements of this strategy include adaptation of livestock systems to the available feed resources and use of more efficient and widespread sub-agro-industrial products and crop residues in cattle feeding systems.

Although, a large amount of research has been conducted on livestock feeding in general, little information is available on aspects such as farming practices for a livestock feeding supplementation system which is a prerequisite for healthy and productive livestock (Dembele, 1995). Hence, this study aimed to identify locally available feed resources and to assess the feeding practices in the Kaolack and Kolda regions in Senegal.

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MATERIALS AND METHODS

Study area: The study was conducted in the Kaolack and Kolda regions in Senegal. The region of Kaolack is located between 14°30' and 16°30' West and 13°30' and 14°30' North while the region of Kolda is located in Upper Casamance in the South-central part of the country at 13°05' North, 14°49' West. The study area was chosen according to reasoned criteria such as the importance of livestock in the region, available databases on farmers and the presence of a dairy farmers' group.

Data collection: Data were collected by surveys schedule designed according to the objectives of the study from May to June, 2012. The survey schedule was prepared based on the following key items: livestock size; available feed resources, feeding practices, purpose of supplementation, supplementation practices (types of supplements distributed, quantities of supplements and beneficiary animals) and milk yield. Data were collected through group discussions, direct interviews and personal direct observations. Two group discussions were carried out consisting of one group discussion with 20 farmers in each study site. Besides, a total of 73 farmers of which 43 (30 men and 13 women) were from Kaolack and 30 (24 men and 6 women) were from Kolda were randomly sampled for individual survey for this study. Responses from the surveyed farmers were recorded directly on the interview schedules.

Data analysis: Data analysis was carried out using Sphinx Plus® 2 v. 4.0 and SPAD® software v. 4.02. Descriptive statistics such as proportions, means and standard deviations were calculated. The χ^2-test was used for comparison of different proportions. The t-test procedure was also used to test for any significant differences between means. The significance level was declared at $p<0.05$.

Multivariate statistical analysis allowed the setting of the most appropriate typology of smallholder farmers based on their feeding strategies. The main purpose of the multivariate statistical analysis was to emphasize the type of links between descriptive variables that characterize the economic and technical results of small farms and create homogenous groups of farmers in relation to the predominant variables. This multivariate analysis was carried out in five steps as described by Mouichi.

Choice of variables: A Principal Component Analysis (PCA) was used to detect the main variables. The choice of variables was performed based on the objectives of the typology. These objectives have been identified and classified as active dummies, additional nominal variables and continuous illustrative variables.

Analysis of the histogram of eigenvalues and choice of axes: From the analysis of the histogram of eigenvalues, we chose the most important axes for the factor analysis. Factors can be interpreted in terms of axes and variables that provide the maximum information.

Description of the factorial axes: The description of the factorial axes was made using the methods introduced in the analysis and the study retained terms whose contributions to the establishment of the axis were high.

Hierarchical cluster and cluster identification: The determination of clusters was performed by analysis of the classification tree or dendrogram. The classification was obtained by cutting the dendrogram. The level of the cut was determined after consideration of the level diagram that showed the existence of early levels. The number of clusters was determined by the level of the cut. We then validated the number of classes selected by performing several classifications and observing the stability of the results.

Analysis of cluster and cluster descriptions: Once the classification was obtained by performing a Multiple Correspondence Analysis (MCA), colors (or symbols) were assigned to individuals depending on the class to which they belong. This approach gives an overall view of the positioning of classes and from the variables that characterize the factorial axes; we described the main characteristics of the classes.

RESULTS AND DISCUSSION

Characterization of farmers and livestock system: The results showed that the main ethnic group of small farmers was Fulani (93 and 80%, respectively in the Kaolack and Kolda regions). The majority of them were illiterate. Three types of livestock systems were identified (Table 1 and 2), extensive, semi-intensive and intensive systems. Most farms were conducted under a semi-intensive system where the animals (except newborn calves) were taken for grazing in the villages during the day and received supplementation in the morning and/or evening after returning from grazing. The most dominant cattle breeds in Kaolack were Gobra Zebu, Ndama Taurin and crossbred cattle which were kept by 88.2, 62.8 and 37.2% of the farmers interviewed, respectively. In Kolda, the dominant cattle breeds were Gobra Zebu, Ndama Taurin, Djakore

Table 1: Ethnic groups and education level of respondents

Variables	Kaolack (%)	Kolda (%)	Total (%)
Ethnic			
Fulani	93	80	87.7
Mandingo	2.3	6.7	4.1
Soninke	0	13.3	5.5
Sereres	4.7	0	2.7
Education			
Illiterate	72.1	83.3	76.7
Koranic education	2.3	3.3	2.7
Primary school education	9.3	10	9.6
Secondary school education	9.3	3.3	6.8
University school education	7	0%	4.1

Table 2: Livestock management

Variables	Kaolack (%)	Kolda (%)	Total (%)
Livestock system			
Intensive system	2.3	0	1.4
Semi- intensive system	88.4	96.7	91.8
Extensive system	9.3	3.3	6.8
Cattle breed			
Ndama	62.8*	100**	78.1
Gobra	88.4*	33.3**	65.8
Djakore	30.2*	3.3**	19.2
Crossbred cattle	37.2*	60**	46.6
Holstein	7	0	4.1
Abondance	0	10	4.1
Montbeliarde	9.3	16.7	12.3
Veterinary visit			
Regular visit	16.3*	3.3**	11
Infrequent	23.3*	30**	26
Visit in case of necessity	58.1*	40**	50.7
No veterinary visit (%)	2.3*	26.7**	12.3

Proportions in the same row with different superscript signs are significantly different at $p<0.05$

Table 3: Herd size and milk yield

Variables	Kaolack	Kolda	Total
Size	37.26±29.81*	77.53±49.42**	53.81±43.59
Number of cows	31.91±26.98*	70.9±43.47**	47.61 ±39.33
Number of dairy cows	6.98±5.73*	12.03±10.08**	9.04±8.13
Quantity of milk/local breed (L)	1.54 ±0.89*	1.51±1.971*	1.53±1.61
Quantity of milk/crossbreed (L)	9.43±6.11*	8.00±2.83*	9.11±5.42

Means in the same row with different superscript signs are significantly different at $p<0.05$

and crossbred cattle (Holstein and local breed; Montbeliard and local breed). In this region, 100% of the farmers reared the Ndama breed. As shown in Table 3, the overall herd size by farm differed significantly across the study regions (Kaolack = 37.26±29.81; Kolda = 77.53±49.42, $p<0.05$). Milk production was significantly higher for crossbred cattle than local breeds in both regions ($p<0.05$). In Kaolack, the average milk yield was 9.43 and 1.54 L for crossbreds and local breeds, respectively. In Kolda, milk production per day per animal was 8.0 and 1.51 L for crossbreeds and local breeds, respectively. The production for local breeds was almost the same in both regions but the production for crossbred cattle was higher in Kaolack than in Kolda ($p<0.05$).

Regarding animal health care, the proportion of farmers confirmed to have received a regular visit from a veterinarian was high in Kaolack (16.3%) compared to Kolda (3.3%) and the difference was significant. Meanwhile, 58.1 and 40% of the farmers in the Kaolack and Kolda regions, respectively, stated that they called for veterinary service when needed, for example, in case of serious illness; otherwise they preferred to use traditional health care methods. However, 2 and 27% of the farmers in the Kaolack and Kolda regions, respectively reported never having a veterinarian visit them.

Farmers' feeding practices: Two main categories of feed resources were available to smallholder farmers in the Kaolack and Kolda regions (Fig. 1), natural pastures (fresh grass, hay and bush straw) and crop residues (millet straw, groundnut haulms, rice straw, cowpea hay and sorghum straw). In the Kaolack region, 97.7, 81.4, 72.1, 67.4 and 62.1% of farmers confirmed that bush straw, fresh grass, millet straw, maize stover and groundnut haulms, respectively were the main basic component of feed

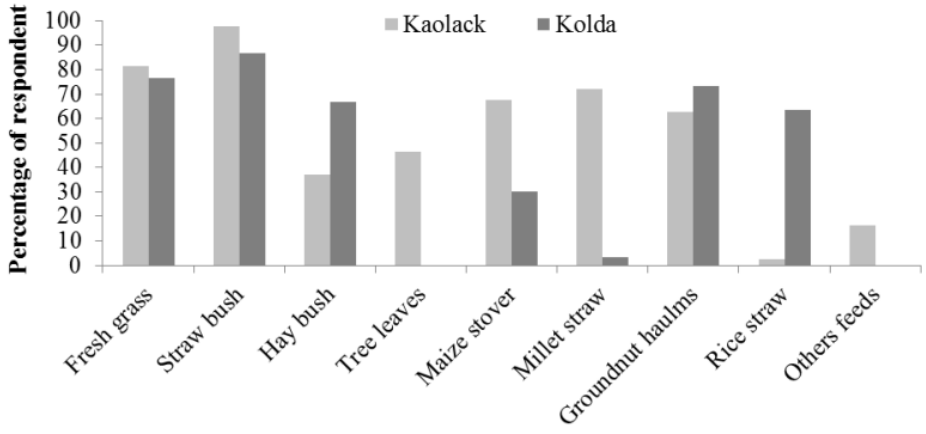

Fig. 1: Basic available feed resources in Kaolack and Kolda regions

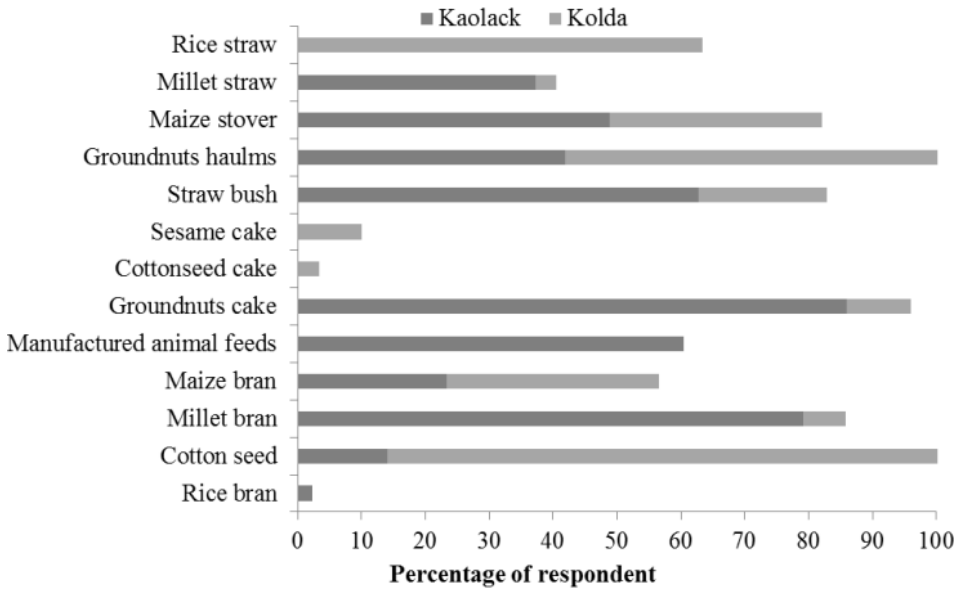

Fig. 2: Feeds used for supplementation in Kaolack and Kolda regions

Table 4: Small farmer's supplementation practices in the Kaolack and Kolda regions

Variables	Practice	Kaolack (%)	Kolda (%)
Supplementation	Yes	97.7	100
	No	2.3	-
Supplementation period	Dry season	92.9	100
	Wet season	-	-
	All year	7.1	-
Frequency of daily supplementation	Once	73.8*	26.7**
	Twice	11.9*	73.3**
	Once or twice depending on available feed resources	14.3	-
Purpose of supplementation	Milk	44.4*	73.3**
	Survival	52.8*	24.4**
	Meat	2.8	2.4
Animal beneficiaries of supplementation	Lactating cows	36.4*	69**
	Pregnant cows	1.5	2.4
	Weak animals	42.4*	23.8**
	Bull	1.5	2.4
	Whole herd	18.2*	2.4*
Amount of supplements distributed	Amount of supplements/lactating cow (Kg DM)	1.93±0.912*	2.74±1.93**

Proportions or means in the same row with different superscript signs are significantly different at $p<0.05$

resources for their animals. In the Kolda region, cattle farmers fed their animals with bush straw (86.7%), fresh grass (76.7%), groundnut haulms (73.3%), rice straw (63.3%) and maize stover (30.3%). The response to our question regarding the practice of supplementation showed that almost all the farmers in both regions gave supplements to their animal. When the responses to the questions about the objective of practicing supplementation were recorded, milk production and survival of the cattle appeared to be the main objectives of the farmers practicing supplementation. The farmers specified that supplementation was mostly conducted during the dry season (91 and 100% in the Kaolack and Kolda regions, respectively) and the supplements were especially reserved for milking cows and/or weak animals.

In Kaolack, 55.8 and 65.1% of the farmers distributed supplements to milking and weak animals, respectively. In Kolda, 96.7% reported giving supplements to milking cows only. Supplementation was given once per day by 72.1% and twice per day by 11.6% of the cattle farmers interviewed. Supplement of 1.93±0.91 kg of DM and 2.74±1.93 kg of DM were given per cattle per day in the Kaolack and Kolda regions, respectively. Table 4 summarizes the farmers' supplementation practices.

Three feed categories were used for supplementation: crop residues, agro-industrial by products and manufactured animal feeds. Specifically, groundnut cake, cotton seed, millet bran, groundnut haulms, bush straw, rice straw and manufactured animal feeds were the most common supplement distributed (Fig. 2). In practice, more

than one type of supplement was distributed. The supplements were distributed to the animals by being poured on the ground in tubs, half-barrels in bags or in mangers (wood). The types of containers used to distribute the supplements often resulted in significant losses of animal feed. Most of the livestock owners in both regions relied on the market to procure animal feed supplements for their animals.

This study demonstrated that most of the farmers had fodder reserves to avoid feed scarcity during the dry season. Crop residues and straw bush (Table 5) were the most common feed collected and stocked by the majority of the farmers for later use during the dry season when the quantity and quality of available fodder from natural pasture has declined drastically. Though supplementation was practiced by small-scale farmers, they reported a diversity of limitation in supplying these supplements. Among the listed problems, high price (20.9%), limited resources (76.7%) and non-availability of supplements at the local market (67.4%) were the most common limitations reported in the Kaolack region. In Kolda, the limitations were mainly the high price of supplements, lack of supplements at local markets and limited resources for 70, 60 and 23.3% of the farmers, respectively. A few farmers (13.3%) reported the remoteness of the area (distance) as one of the limitations to accessing manufactured supplements. However, 3.3% of the respondents confirmed that they did not face any problem in feed supplement supply.

Relationship between quantity and type of supplement distributed with milk production: The study showed that milk production was positively associated with the supplementation practice. However, the results show that the dependence between these two variables was not significant ($p>0.05$).

While taking into account the specifics of each type of supplement, the analysis showed that groundnut cake had a higher significant influence on milk production than other types of supplements. It was followed by cotton seed (Table 6).

Table 5: Fodder reserve ownership by smallholder farmers in the Kaolack and Kolda regions

Variables	Kaolack (%)	Kolda (%)	Total (%)
Bush hay	67.4*	23.3**	49.3
Groundnut haulms	39.5*	80**	56.2
Millet straw	41.9*	13.3**	30.1
Maize straw	48.8*	26.7**	39.7
Cowpea hay	7	6.7	6.8
Rice straw	-	60	24.7
Sorghum straw	4.7	-	2.7

Proportions in the same row with different superscript signs are significantly different at $p<0.05$

Typology of small famers

Identification of variables used in the multivariate statistical analysis: For this cluster analysis, 22 variables were selected. Eleven of them were active dummy variables (Table 7), seven additional nominal variables were illustrative (Table 8) and four of them were continuous variables illustrative (Table 9).

Analysis of the histogram of eigenvalues and choice of axes: The analysis of the histogram of eigenvalues allowed us to select the most relevant axes factor analysis. We therefore selected two factorial axes that explain at least 20.85% of all information.

Hierarchical cluster and cluster identification: The hierarchical cluster allowed us to obtain the histogram of levels index and the classification tree or dendrogram. The histogram of levels index had a drop in level two. This level indicates that the stall cutoff level of the dendrogram must be between the knot of level two and level three. After cutting the dendrogram at level 3, there were three classes (Fig. 3).

Cluster analysis and cluster descriptions: This partition was coupled to the description of factors provided by PCA to describe the farmers on the basis of their feeding practices and the distribution of classes in factorial 1.2 (Fig. 4 and Table 10).

Description of the different type of farmers on the basis of the feeding practices and milk production: Three types of small farmers (type 1-3I) were identified based on the criteria of supplementation practices and milk production (Table 11).

Table 6: Correlation between types of supplements distributed and milk yield by lactating cows/day

Correlation	Correlation-quantity of produced milk/cotton seed distributed	Correlation-quantity of produced milk/quantity of millet bran distributed	Correlation-quantity of produced milk maize bran distributed	Correlation-quantity of produced milk/groundnut cake distributed
Equation of regression line	Milk produced = 0.2+1.30* quantity of cotton seed distributed	Milk produced = 1.16+0.04* quantity of millet bran distributed	Milk produced = 1.13+0.11* amount of maize bran distributed	Milk produced = 0.13+1.36* amount of groundnut cake distributed
Correlation coefficient	0.64 (R^2 = 0.40 grain cotton distributed accounts for 40% of the variance of the quantity of produced)	0.02 (R^2 = 0 Quantity of millet bran distributed explains 0% of the variance in quantity of produced milk	0.05 (R^2 = 0 quantity of maize bran distributed explains 0% of the variance in quantity of produced milk	0.75 (R^2 = 0.56 quantity of groundnut cake distributed explains 56% of the variance in quantity of produced milk
Dependence	Low significant	Not significant	Not significant	Significant

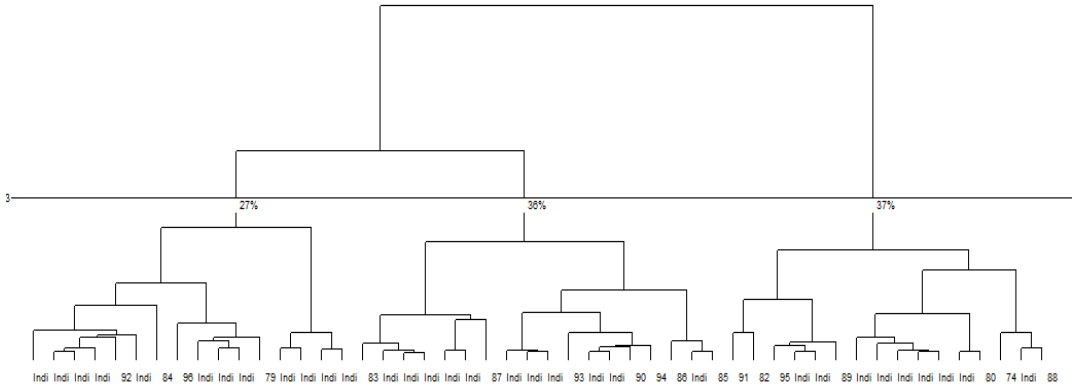

Fig. 3: Ascending hierarchical classification dendrogram after cutting

Table 7: Dummy variables active

Variables	Terms
Practice of supplementation	Yes
	No
Animal beneficiaries of supplementation	Lactating cows
	Pregnant cows
	Weak animals
	Bulls
	Whole herd
Priority of supplementation to lactating cows	Yes
	No
Frequency of daily supplementation	Once
	Twice
	Once or twice depending on available feed resources
Purpose of supplementation	Milk
	Survival
	Meat
Fodder reserve ownership	Yes
	Non
Supplement distributed	Cotton seed
	Groundnut cake
	Animal industry feeds
	Groundnut haulms
	Rice straw
	Millet bran
	Bush hay
Limitation in supplement supply	Lack of means
	High price
	Low feed (supplement) supply at local market
	Remoteness of the area

Table 8: Dummy variables illustrative

Variables	Terms
Region	Kaolack
	Kolda
Gender	Male
	Female
Education level	Illiterate
	Primary school education
	Secondary school education
	University school education
	Koranic education
Cattle breed reared	Ndama
	Gobra
	Djakore
	Crossbred cattle

Table 9: Continuous variables illustrative

Variables	Terms
Herd size	Mean±standard deviation
Quantity of produced milk	Mean±standard deviation

Type 1 represented 35.49% of all surveyed farmers. They were all male, coming from both localities (Kaolack or Kolda) and most were not educated. They mostly owned Gobra (41.1%) and Djakore (38%) cattle breeds. In this type, only weak animals were subjected to supplementation (60%). The feed supplement was distributed once or twice per day at the rates of 45.12 and 36.99%, respectively. The most common supplements distributed were millet bran, maize stover and groundnut cake. The average milk production was 1.5±0.71 L per cow per day. In this group, the majority of the farmers had difficulty accessing supplements due to lack of means.

Type 2 included 27.1% of the surveyed farmers. Most of the farmers in this group were well educated. They kept Ndama (34.15%) and Gobra (40.25%) cattle and some had crossbred cattle (25.6%). The supplementation purposes were mainly milk production (72.40%) and animal survival (65.3%). The farmers in this group supplemented in most cases twice per day (68.1%) with cotton seed, groundnut cake, groundnut haulms and manufactured animal feeds. The average milk production in type 2 was 2.99±0.5 L per cow per day.

Type 3 contained mainly farmers from the Kolda region (71%) and represented 37% of the farmers surveyed. Ndama was the dominant cattle breed kept by these farmers (75.3%). The farmers practiced feed supplementation, mostly for milk production (75.34%). Hence, milking cows were privileged for supplement distribution. Some farmers of this group gave supplements once per day (53.42%) while others gave supplements twice per day (36.99%) and they mostly gave cotton seed, groundnut haulms, rice straw and maize bran. Most of the farmers (78.8%) possessed fodder

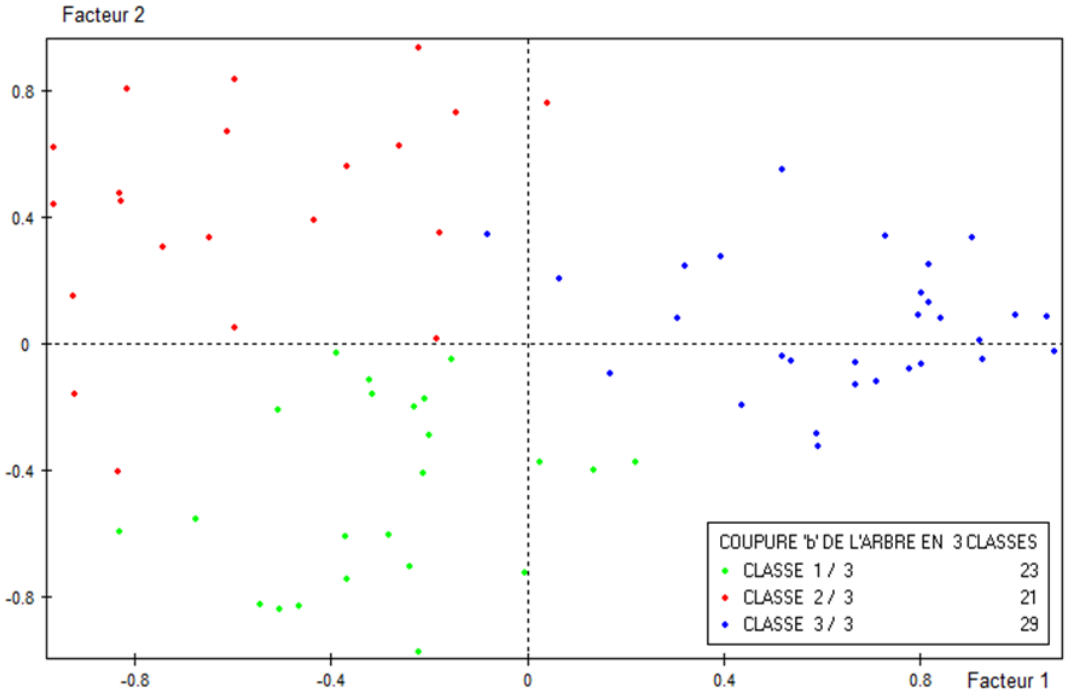

Fig. 4: Disposition of farmers according to factor axes characteristics

Table 10: Definition of factorial axes

Factorial axe	Positive	Negative
1	Region of Kolda	Region of Kaolack
	Cattle breed: Ndama and Gobra	Cattle breed: Gobra
	Purpose of supplementation: milk	Purpose of supplementation: milk
	Supplements distributed once per day	Supplements distributed twice per day
	Supplements distributed: cotton seed, rice straw and groundnut haulms	Supplements distributed: Groundnut cake, groundnut haulms and animal industry feeds
	Limitation in supplying supplements: high price	Limitation in supplying supplements: supplement shortage supply at local market
	Lactating cow got the first priority of receiving supplement	-
2	Region of Kolda	Region of Kaolack
	Education level: secondary and university	Education level: illiterate
	Cattle breeds: Ndama and crossbred cattle from AI	Cattle breed: Gobra and Djakore
	Purpose of supplementation: Milk and survival	Purpose of supplementation: Survival
	Lactating cows got the first priority for receiving supplements	Weak animals got the first priority for receiving supplements
	Supplements distributed once or twice per day	Supplements distributed once per day
	Supplements distributed: cotton seed	Supplements distributed: Millet bran, straw bush
	-	Limitation in supplying supplements: lack of means

reserves to prevent feed scarcity during the dry season. However, the farmers of this group reported the high cost of supplements as the main problem in accessing supplements. The average milk production in this group was 2±0.3 L per cow per day.

The prevailing livestock system in the study area is a semi-intensive system which is highly attributed to the increasing integration of crop-livestock farming systems in by many smallholders across Sub-Saharan Africa. This result is consistent with the findings reported by Sere *et al.* (1996) and Habimana *et al.* (2014) that showed a predominance of semi-intensive systems in Sub-Saharan Africa. Habimana *et al.* (2014) explained that farmers in Kaolack and Kolda are currently likely to abandon the traditional extensive system and transhumant practices for a less extensive system because of many problems they face today such as long, tiring and challenging distances travelled, insecurity problems and conflict with farmers. Farmers tend to adopt a semi-extensive system to profit from crop residues as animal feeds. This is similar to findings from other researchers across Sub-Saharan Africa. For example, in Somda *et al.* (2004) stated that crop and livestock production are integrated through the use of

Table 11: Description of different typologies of small farmers on the basis of the feeding practices and milk production

	Groups		
Variables	1	2	3
Percentage	35.49%	27.1%	37%
Region	Kaolack: 58.90% Kolda: 41.1%	Kolda: 41.1% Kolda: 71%	Kaolack: 58.90% Kaolack: 29%
Gender	Male almost at 100%	Female: 20.55% Male: 79.45%	Female: 20.55% Male: 79.45%
Education level	Illiterate Primary school education Koranic education	Secondary school education University school education Primary level	Illiterate Primary school education
Dominant breed	Gobra: 41.10% Djakore: 38%	Ndama: 34.15% Gobra: 40.25% Crossbred cattle: 25.6%	Ndama: 75.3% Gobra: 20.55%
Objective of supplementation	Survival: 80%	Survival: 65.3% Milk: 72.4%	Milk: 75.34%
Frequency of supplementation	Once per day: 45.12% Twice per day: 36.99%	Once per day 21.55% Twice per day 68.1%	Once per day: 53.42% Twice per day: 36.99%
Animal beneficiary of supplementation	Weak animals 60%	Lactating cows: 62% Weak animals: 59%	Lactating cows: 71.3%
Supplements used	Millet bran Bush hay Groundnut cake	Cotton seed Groundnut cake Animal industry feeds Groundnut haulms	Cotton seed Rice straw Groundnut haulms Millet bran
Average milk produced (L)	1.5±0.711	2.99±0.5	2±0.3
Fodder reserve ownership	65%	80.7%	78. 08%
Limitation in supplement feeds supply	Lack of means (80%)	Low feeds (supplements) supply at local market (62%)	High price (60%) Lack of means (33%)

animal traction and manure for cropping and the use of crop residues as animal feeds. Similar production systems are practiced across West African production systems, characterized by the fact that most farmers are involved in crop farming and livestock keeping (Powell *et al*., 2004; Umutoni *et al*., 2015). The dominance of indigenous livestock breeds in the study sites was also reported by Habimana *et al*. (2014) in this area. Particularly, in the Kolda region, farmers reared mostly Ndama cattle which are trypanotolerant breeds; this is due to high tsetse fly infestation (Somda *et al*., 2004). Moreover, due to the implementation of artificial insemination programs in Senegal over the last decade, farmers also reared crossbred cattle, an improvement of the local breeds. The aim of this program was to increase livestock production at the small-scale level, thereby increasing food security at the smallholder farmer's level. However, the program has not yet reached the expected outcomes because the conditions required for these crossbred cattle to attain high milk production level are not fully present at the small-scale level but there are promising results, especially over the coming years.

The number of cattle reared by the farmers was significantly higher in Kolda than in the Kaolack region. The low number in Kaolack may result from intensive crop farming which leads to limitation of natural pasture. A variation in the size of herds per household from place to place has been reported in a number of studies such as in a study performed by Teklu *et al*. (2011) in Ethiopia. This variation is due to the availability of feed resources, prevalence of diseases, livestock management systems, tradition and the involvement of farmers in diverse activities (Zewdu *et al*., 2003).

This study indicated that feeding strategies are influenced by seasonality in feed quality and availability. The results showed that the animals received supplements during the dry season because of feed shortage which is a result of depleted natural pastures. The basic feed resources reported in this study have been reported in other studies on small-scale farms in developing countries (Devendra and Sevilla, 2002; Ayantunde *et al*., 2005; Teklu *et al*., 2011). When natural pasture becomes less available during the dry season, the farmers in the study area supplement crop residues and other agricultural by-products for their livestock. The use of crop residues as supplements varied between the two study areas depending on the crop grown in each area. Thus, the nature of the crop determines the availability of crop residues and crop by-products that could be potentially used as a feed resource. In that case, the residues and crop by products are easily accessible. For example, groundnut cake and bran millet were the most common supplements used in the Kaolack region because groundnut and millet are the main crops grown in the area. The farmers in Kolda used as supplements mainly cotton seed, groundnut haulms and rice straw because cotton, groundnut and rice are the dominant crops in that region. Other studies (Somda *et al*., 2004; Mengsitie, 2007; Teklu *et al*., 2011; Addisu *et al*., 2012) reported that crop residues have been the main source of

livestock feeds, especially for ruminant animals, during the dry season after natural pasture and the farmers supplemented with crop residues and agricultural by products. Although, some respondents supply manufactured animal feeds to supplement their animals, the use of manufactured animal feeds is not widely developed in the study areas due to the limited availability of manufactured animal feeds at the local market because of the remoteness of the area and the high cost involved. Amare (2006) reported that the feeding of agro-industrial by-products and manufactured animal feeds are prioritized based on the productive potential of the animal.

Indeed while supplementing, farmers have a specific objective which determines the category of cattle receiving a supplement. In Kaolack, where the objective for supplementation for the majority of the farmers was either milk or survival, weak animals and milking cows were prioritized whereas in Kolda where the farmers mainly supplemented to improve milk production, the first priority for supplementation was milking cows. Although, supplementation was practiced, the results revealed that it was conducted haphazardly, lacking any kind of measurement. This was a result of inadequate knowledge of the types and ways of using supplements, ignorance of opportunities for on–farm preparation of supplement mixtures and the weakness of extension services to ensure a good understanding of the supplementation being undertaken by smallholder farmers. In addition, supplementation practice has been hampered in the study area by the high cost of purchasing feeds, lack of means for some farmers and low feed supply at the local market due to the remoteness of the area.

Under these conditions that limit supplementation practice and particularly during the dry season, feed remains a serious constraint to increased livestock production, especially milk production. Indeed, the results of this study showed low milk production during the dry season in both regions. Although milk production by the crossbred cattle was significantly higher than that of the local breeds, the production of crossbred cows remain low compared to the expected production. This low production could be attributed partly to the feed shortage both in terms of nutritive quality and quantity. This concurs with findings from previous studies (Somda *et al*., 2004; Hossain *et al*., 2005; Bebe *et al*., 2008). Rahman *et al*. (2008) also indicated that the introduction of improved breeds without the supporting infrastructure (veterinary support, housing, sufficient feed, etc.) is not significantly beneficial.

Despite the low productivity of cows during the dry season, there is a difference in the amount of milk produced by the cows subjected to supplementation. Indeed, further analysis of the results of this study on the relationship between supplementation and milk production showed a significant effect of supplementation on the quantity of milk produced. Cows subjected to supplementation produce much more milk than those that were not supplemented and the difference varied with the type of supplement distributed to the animal. This is in agreement with the results by Ba *et al*. (1998) and Dieye *et al*. (2002). This study determined that the use of groundnut cake as a supplement has a higher significant influence on milk production than other supplements. The economic analysis of supplementation indicated considerable financial benefit to farmers (Devandra and Sevilla, 2002).

In addition, this study highlighted three types of farmers based on their characteristics, feeding strategies and milk production. The first point to highlight from this typology is that the groups are formed according to the location; this is understandable as normally farmers who live in the same area with the same reality tend to adopt the same technology and strategies for their livelihoods as observed earlier by Habimana *et al*. (2014). In this regard, Dembele (1995) also observed that farmers are divided into groups in Mali according to geographical areas. The farmers of type 1 are extensive because they use less input in their production system; they rely mainly on the basic element available to them which results in low production. We argue that they are more highly vulnerable than the other groups in terms of livestock production. The two other types (2 and 3) are willing to use input to enhance their production. These types are more suitable for the programs that require a kind of commitment and investment from farmers; they will willingly adopt any technology that will help them to increase their production. For example, they can be selected for programs of artificial insemination because they can invest in feed supplementation for their animals which is a prerequisite for the success of this program (Habimana *et al*., 2014). Type 3 farmers had a higher level of education than the farmers in the other groups. This suggests that they may be more production-oriented than the other groups; hence, they can be targeted for livestock programs that require a high level of knowledge by the farmers.

To attain the projected per capita milk consumption for Sub-Saharan Africa by 2020, Delgado *et al*. (2001) opined that more effort on the feeding of dairy cows is required to increase milk production. For this purpose, this study has shown important needs: educating farmers on supplementation practices and their impact on milk production, formulating policies to develop forage production, integrating agro-industrial by products and more manufactured feeds in the diet of the dairy cows and conducting further study on crop residue use and utilization as animal feed.

CONCLUSION

In addition, based on feeding strategies and milk production, three groups of farmers were identified. The study revealed important needs, such as educating farmers on supplementation practices to improve milk production.

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