A chopper as appropriate tool for livestock production and effects on silage nutritive characteristics based-maize-sorghum and millet in Burkina Faso

Millogo Vinsoun[1,2*], Kéré Michel[1,2], Sissao Mariétou[3], Sidibé-Anago Alice Gisèle[6], Koudougou Hafsatou[1], Robert Burdick[4] and Timothy Harrigan[5]

[1]Innovation Hub, Appropriate Scale Mechanization Consortium (ASMC), Institute of Rural Development, Nazi Boni University, P.O. Box 1091 Bobo-Dioulasso 01, Burkina Faso.

[2] Laboratoire de Recherche et d'Enseignement en Santé et Biotechnologie Animales, Institut du Développement Rural, Université Nazi Boni, 01 BP 1091 Bobo-Dioulasso 01, Burkina Faso.

[3] Centre Universitaire de Tenkodogo/Université Thomas SANKARA, 12 BP 417 Ouagadougou, Burkina Faso.

[4] Tillers international, 10515 OP Ave E Scotts, MI 49088, USA

[5] Department of Biosystems and Agricultural Engineering, Michigan State University, 524 S. Shaw Lane 120B, East Lansing, MI 48824, USA.

[6]Institut de l'Environnement et de Recherches Agricoles, 04 BP 8645, Ouagadougou 04, Burkina Faso.

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Abstract: Burkina Faso is a Sahelian country with a long dry season when the livestock base-pasture grazing is facing a severe forage shortage. The feed gap can drastically affect ruminant's production performances, particularly cattle. In order to contribute to feed availability in the dry season, an experiment was carried out on forage production and silage production using a forage chopping tool called appropriate scale mechanization consortium chopper (ASMC chopper). The experiment took place at the ASMC project site at Koumbia Tuy's province in the Hauts-Bassins Region, Burkina Faso (West Africa). Maize, sorghum and millet were used to produce silage and evaluate nutritive values. The present study hypothesized that: i)-the chopped forage size with ASMC chopper doesn't significantly modify silage quality; ii)-the nutritive value of forage is conserved during the ensiling process. Chopping rate were 6.13 ± 0.13 kg/min, 6.08 ± 0.91 kg/min and 6.33 ± 0.17 kg/min for maize, millet and sorghum respectively. The forage was silage in 50 and 200 L drums. In term of forage quality, for maize NDF (63.29 to 64.83%), ADF (29.6 to 29.72 %), crude protein (11.07%) did not change. It was found 69.3 to 68.39% of NDF, 36.51 to 36.17 % of ADF and 6.96 to 7.06% of crudes proteins for sorghum. NDF content (70.39%) did not change for millet and the average of 39.9 to 41.42% for ADF and 7.83 to 6.44% for crudes proteins were respectively found. At the end of the process, silage was used to feed the farmer's lactating cows to see feed intake. Maize silage dry matter feed intake was higher in cow number 2 at 3.25 ± 0.99 kg than in cow number 4 at 2.44 ± 1.49 kg. In conclusion, ASMC chopper is an appropriate tool for silage making which is a good strategy for livestock feeding system and feed availability in Burkina Faso with conserved feed quality during the dry season.

Keywords: Maize, sorghum, millet, chopper, ensiling, silage, feeding, livestock, Burkina Faso

INTRODUCTION

Livestock farming is an important sector for the West African economy. Its average contribution to Gross Domestic Product (GDP) at the regional scale is 44% (Kagoné *et al.*, 2009). It is an important source of income, livelihoods, nutrition and food security, as well as resilience in many parts of Africa (Herrero *et al.*, 2014). In Burkina Faso, more than 80% of households practice livestock production and 92% is mainly rural smallholder farmers. It has a major place in the national economy (FAO, 2016). Its contribution covers around 18% to export values and around 12% to GDP (MRAH, 2014). The national statistics on livestock showed around 8,912,532 of cattle, 9,007,585 of sheep and 13,486,909 of goats (MRA, 2015).

There is therefore a great challenge to successful feed those animals across the country. Thus, livestock farming is facing issues like land tenure insecurity and drastic reduction of lands for grazing due to the increase in crop-related activities. In such context, feeding appears as main constraint which gives back animal production in Burkina Faso. It has been identifying that natural pasture based-livestock system is uneven activities due to increasing degradation of environment (Zampaligré *et al.*, 2013; Kima *et al.*, 2015). Climatic change and human actions are the most important factors which explain this process (Rigolot *et al.*, 2017).

In addition, during the long dry period, forage loses its nutritive quality (Millogo *et al.*, 2019). The decrease in pastoral resources increases the problem of the viability of existing livestock systems (Zampaligré *et al.*, 2013; Kima *et al.*, 2015). Moreover, cattle have more negative impacted by the long dry season with poor forage than any others domestic ruminant species. There is a need to overcome by promoting forage production and feeding system as integrated approach. In country with very short rain season, efforts should be focus on forage conservation such as hay and silage. Previous works have shown different strategies and revealed that silage production is not still well handled by farmers in Burkina Faso (Kiéma *et al.*, 2008 and Simian, 2017). Today, animal still plays a role in the integrated farming system as drawn-force in Burkina Faso. Millogo *et al.* (2020) showed that mechanization can contribute to increase crop production if draft oxen have good body score. However, this study has shown that 25% of animals were under body condition score of four (4). In order to contribute to forage production, a tool for chopping forages was designed and adapted by the appropriate scale mechanization consortium (ASMC) through its innovation hub in Burkina Faso in 2018. This tool called chopper is able to chop fresh forage and crop residues to make silage, hay, and compost and therefore adapted to smallholder farmers as the targets users. The chopper can improve forage production and feeds for animals, especially for cattle. Before scaling the tool, a pre-test was carried out on maize, sorghum and millet. Data on forages quality, chopped size, ensiling process were recorded during the process. Furthermore, at the end, a dry matter intake trial was carried out on lactating cattle as the main beneficiaries of the technology. The present study hypothesized that: i)-the chopped forage size with ASMC chopper doesn't significantly modify silage quality; ii)-the nutritive value of forage is conserved during the ensiling process. Therefore, the aim of the study was to contribute to better forage conservation in Burkina Faso to be used all year around and check if the chopper could be used as relevant tool for livestock production.

I. Material and methods

1. Experiment site

The study was carried out in the rural commune of Koumbia (11° 14' 0" North and 3° 42' 0" West). It is a demonstration site of the appropriate scale mechanization consortium (ASMC) located in the Tuy's province in Burkina Faso (Hauts-Bassins Region, ASMC project area). The experiment was conducted at Ly Birgui's farm at Koumbia. The climate is sudanian type with long dry season (from November to April) and a short rainy season (from May to October). The average annual rainfall varies between 800 and 1,100 mm with peak during June, august and September (Vall *et al.*, 2006). A record shows in 2018 showed 100 mm as highest average of the rain is recorded in august. It is also the growing season of annual grasses in that area. In general, a gravelly, a hydromorphic and sandy soils covered the study area.

2. Forage production

2.1. Crops materials

Three crops seed were used: maize variety SR21, millet variety SCHVA 69 and sorghum variety Sariaso 16. All crops used were selected by Institute of Environment and Agricultural Research (INERA) of Burkina Faso.

2.2. Experimental design

A completely randomized block design experiment with four treatments and eight (08) replications was carried out. A total land used was 5,760 m² divided into 32 plots of land measuring 27 m x 6 m. A total of 08 plots of land were used to grow sorghum, millet and maize, respectively. An early planting took place between 9 and 23 May in year 2018 using the ASMC planter (Millogo *et al.*, 2018). Weeding, fertilization and the ridging were applied according to the recommended itinerary of Institute of Environment and Agricultural Research (INERA)

2.3. Forage harvesting

The crops were cut as forage for silage production. After three months of growth, the entire whole plant of each crop was cut from 25 to 30 august 2018. The crops were cut at milk stage of small grain. The machetes were used to mow the crops and the tarpaulins were used to lay the forages down to prevent it from soil contamination. Each crop was cut at 5 cm above soil to avoid contamination. The cutting process was conducted by a team of 15 graduate students and 03 indigenous farmers. The forages were collected using an animal-draw cart pooling by man due to the close chopping place with the field. The working team was divided into cutting team and collecting team. The forages were collected and dried on tarpaulin before using the chopper for chopping process (Pictures 1 et 2).

Pictures 1 and 2: Forage harvesting and transport (Millogo, 2018)

3. Chopper and characteristics

The chopper is a forage chopping tool designed and adapted by the appropriate scale mechanization consortium (ASMC) project in Burkina Faso. It was made using local materials by artisans (blacksmiths) in Burkina Faso. It is a very important tool for better ensiling process by reducing forage in small species for microbial action.

The chopper can be used to cut straw for composting as well as making hay. It is easy reproducible by artisan as advantages of being local made. The maintenance doesn't recommend that much and the chopper has two blades (master parts) that can be replaced. Moreover, it is a manual tool and adapted to human energy especially for smallholder farmers in Burkina Faso (West Africa) and elsewhere.

The ASMC chopper is a simple tool with total weight of 61.5 kg. The measures parameters are 145 cm high, 128 cm long and 50 cm wide. The chopper has two blades for chopping and its average speed is 6 kg fresh forage per minute. The chopped size of forage is 2.5 cm. The chopping yield in hour is 500 kg of forages.

4. Ensiling.

4.1. Chopping, drying and measure of water content of the forages

The forage was chopped using the ASMC chopper. Before packaging, a microwave star matic was used to estimate the moisture content of the forage to be made for silage, given the conditions of the working environment (Koudougou, 2018). A balance was used to measure forages samples of 500 g each (Koudougou, 2018).

Picture 3: ASMC chopper in use (A) with the chopped forage (B) Millogo (2018).

Sampling took place at the time of settling and involved small barrels. Each layer of forage was taken as the final forage sample. The crushed forage was placed in the microwave at 100°C. Every 15 minutes, the sample was removed from the microwave and weighed until a stable weight which indicates that the sample was dry.

The general following calculation was applied for the moisture content:

$$H (\%) = ((w_1 - w_2)/w_1) \times 100$$

W_1 being the fresh weight of the initial sample; W_2 being the dry weight of the final sample.

4.2. Filling the plastic can and sealing

A total of 14 barrels of 200 L and 18 barrels of 50 L were used as silos for forage storage. Large barrels were able to hold an average of 96.51 ± 1.55 kg of forages and small barrels were able to hold an average of 20.57 ± 1.09 kg of forages. The plastic bags were placed in the barrels before filling so that the forage was in an anaerobic environment. Drumsticks were used to pack the forage into the barrels.

Packaging was done in 200 L and 50 L drums using drumsticks. The inside of the barrels was covered with plastic bags of consistent thickness. In order to obtain a better sealing, it was made in layers (Picture 3A). As for the hermetic sealing of the barrels, after having finished welling packaging, the plastic film was folded on the top before putting the lid of the barrel. The rims were sealed first with tape and then with film paper (Picture 3B).

Picture 4 : Packing the fodder in a drum (A), covering the packed fodder with plastic film (B), sealed barrels (C) and opening a barrel after 07 months of ensiling (D) (Koudougou, 2018).

4.3. Methods for determining forage composition

Dry matter and mineral contents were determined using oven à +105°C during 12 hours and using desiccator at +550°C during 4 hours, respectively. The ADF, NDF, crude proteins (CP) crude cellulose contents were determined using the general official methods of analysis for chemical principle (A.O.A.C, 1990).The data are presented in percentage (%).

5. Testing the silage on lactating cows

Four (04) lactating cows called Zebu Peulh (*Bos indicus*) were included for testing the silage. All cows belong to farmer and were veterinary treated before the trial. Thus, three cows were primiparous and one multiparous. The stage of lactation was between three and four months. The trial involved feeding two cows and keeping the other two on pasture grazing as controls. The two cows were fed 07 kg of silage in the morning before grazing and 1.3 kg of cottonseed cake in the evening. All the animals went to the pasture in the mornings and in the evening they received a mixture of rice bran and maize from the farmer. Milking was done by hand and took place in the morning at 6 am and in the evening at 6 pm. Milking was done twice a day which is not common in the traditional milk production system. It has been shown that milking frequency has a positive effect on the milk production of the Zebu Peulh cow (Sissao *et al.*, 2016). Milk stimulation for ejection was done by calf as typical practice in restricted suckling system in Burkina Faso (Millogo *et al.*, 2012). The trial period was limited to 30 days due total amount of silage produced during the trial. However, milk quantity measurements were continued up to two weeks after the feeding base-silage in order to observe the cross-over effects of the feeding. Those measurements are not included here.

6. Data collection and statistical analysis

The studied parameters were: (i) the length of the pieces of silage forage and the labor time with the Chopper, (ii) the nutritional value of crops (corn, sorghum and millet) before silage and after silage, (iii) the amount of milk produced by the cows fed with the silage, (iv) the silage feed intake. The Data were subjected to analysis of variance (ANOVA) using SPSS (Statistical Package for Social Sciences) software. The comparison of the means was performed using Tukey test. The difference between means was considered to be significant when p-value was ≤ 5%.

II. Results

1. Efficiency of the ASMC Chopper

Stem and leaf length and the working time of the chopper are recorded in Table 2. Leaf lengths for maize, millet and sorghum were 5.00 ± 0.72, 5.68 ± 1.12 and 5.91 ± 1.36 respectively. Stem lengths for maize, millet and sorghum were 2.30 ± 0.32; 2.31 ± 0.11 and 2.89 ± 0.21, respectively. The chopper works an average of 6.13 kg of maize, 6.08 kg of pearl millet and 6.33 kg of sorghum in a minute.

Table 2: Lengths of the forage pieces and working time of the ASMC Chopper

Cereals	Leaf length (cm)	Stem length (cm)	Labor time	
			kg/minute	g/second
Maize	5.68 ± 1.12[a]	2.30 ± 0.32[a]	6.13 ± 0.13[a]	102.17 ± 2.20[a]
Tiny millet	5.91 ± 1.36[a]	2.31 ± 0.11[a]	6.08 ± 0.91[a]	101.28 ± 2.23[a]
Sorghum	5.00 ± 0.72[a]	2.89 ± 0.21[b]	6.33 ± 0.17[a]	105.45 ± 2.29[b]

The averages of the same column with the same letters are not different ($p > 0.05$) but those with different letters are significantly different ($p \leq 0.05$).

2. Nutritive value of raw crops

Raw crops nutritive value is presented in Table 3. Thus, maize showed higher nutritive value compares with sorghum and millet. However, sorghum and millet showed similarities in DM and NDF content. Chemical analysis of maize before and after ensiling showed that silage changed a few parameters of the nutritive value of maize, namely DM content changed from 93.19 ± 0.29 to 95.09 ± 1.17% and crude cellulose from 33.95 ± 1.35 to 36.65 ± 0.94% (Table 4). For sorghum, ensiling changed only the DM content from 94.54 ± 0.86 to 96.31 ± 0.57%. The other parameters did not change significantly. The ensiling changed a few parameters of the feed nutritive value of millet, namely DM content, from 94.80 ± 0.37 to 96.22 ± 0.43%, and crude protein, from 7.83 ± 1.02 to 6.44 ± 0.60%.

Table 3: Nutrients content of forage prior to ensiling

	Maize	Sorghum	Millet
DM (%)	93.19 ± 0.29^{a}	94.54 ± 0.86^{b}	94.80 ± 0.37^{b}
MM (%)	7.32 ± 0.47^{b}	6.44 ± 0.12^{a}	9.55±0.49^{c}
NDF (%)	63.29 ± 1.15^{a}	69.30 ± 0.90^{b}	70.39 ± 0.90^{b}
ADF (%)	29.63 ± 0.98^{a}	36.51±1.21^{b}	39.95 ± 1.35^{c}
CC (%)	33.95 ± 1.35^{a}	42.42 ± 2.06^{b}	44.36 ± 1.35b^{c}
CP (%)	11.07 ± 0.95^{c}	6.96 ± 0.85^{a}	7.83 ± 1.02^{b}

DM: dry mater content (%); Mineral Mater content (), NDF: neutral detergent fiber (%), ADF: Acid Detergent Fiber (%); CC: Crude Cellulose (%); CP: crude proteins (%). The averages of the same column with the same letters are not different ($p > 0.05$) but those with different letters are significantly different ($p \leq 0.05$).

Table 4: Influence of silage on the conservation of the nutritive value of different plants

	Maize		Sorghum		Millet	
	Before silage	**After silage**	**Before silage**	**After silage**	**Before silage**	**After silage**
DM (%)	93.19 ± 0.29^{a}	95.09 ± 1.17^{b}	94.54 ± 0.86^{a}	96.31 ± 0.5^{b}	94.80 ± 0.37^{a}	96.22 ± 0.43^{b}
MM (%)	7.32 ± 0.47^{a}	7.38 ± 0.35^{a}	6.44 ± 0.12^{a}	6.68 ± 0.35^{a}	9.55 ± 0.49^{a}	9.59 ± 0.18^{a}
NDF (%)	63.29 ± 1.15^{a}	64.83 ± 2.53^{a}	69.30 ± 0.90^{a}	69.39 ± 2.53^{a}	70.39 ± 0.90^{a}	70.39 ± 1.94^{a}
ADF (%)	29.63 ± 0.98^{a}	29.72 ± 0.75^{a}	36.51 ± 1.21^{a}	36.17 ± 3.22^{a}	39.95 ± 1.35^{a}	41.42 ± 1.36^{a}
CC (%)	33.95 ± 1.35^{a}	36.65 ± 0.94^{b}	42.42 ± 2.06^{a}	42.81 ± 1.23^{a}	44.36 ± 1.35^{a}	44.48 ± 0.63^{a}

CP (%)	11.07 ± 0.95^{a}	11.07 ± 0.26^{a}	6.96 ± 0.85^{a}	7.06 ± 0.80^{a}	7.83 ± 1.02^{b}	6.44 ± 0.60^{a}

DM: dry mater content (%) ; Mineral Mater content (%), NDF: neutral detergent fiber (%), ADF: Acid Detergent Fiber (%); CC: Crude Cellulose (%); CP: crude proteins (%). The averages of the same column with the same letters are not different ($p > 0.05$) but those with different letters are significantly different ($p \leq 0.05$).

3. Silage feed intake and effect on milk production

Milk production showed consistency for cow number 2 and 3 which received silage. Cow number 1 and number 4 cows did not receive silage and showed irregularly milk production. Milk production of cow's number 2 and number 3 dropped from the 4th measurement, which corresponds to end silage feeding (Figure 1A). Maize silage DM feed intake was higher in cow number 2 at 3.25 ± 0.99 kg than in cow number 3 at 2.44 ± 1.49 kg. The intakes of cows 2 and 3 are 46 ± 14% and 35 ± 21%, respectively (Figure 1B and 1C). In the following graphic, cows are organized in group 1 (cows 1 = received silage, number 2 and 3) and group 2 (cows 2 = without silage, cows number 1 and 4).

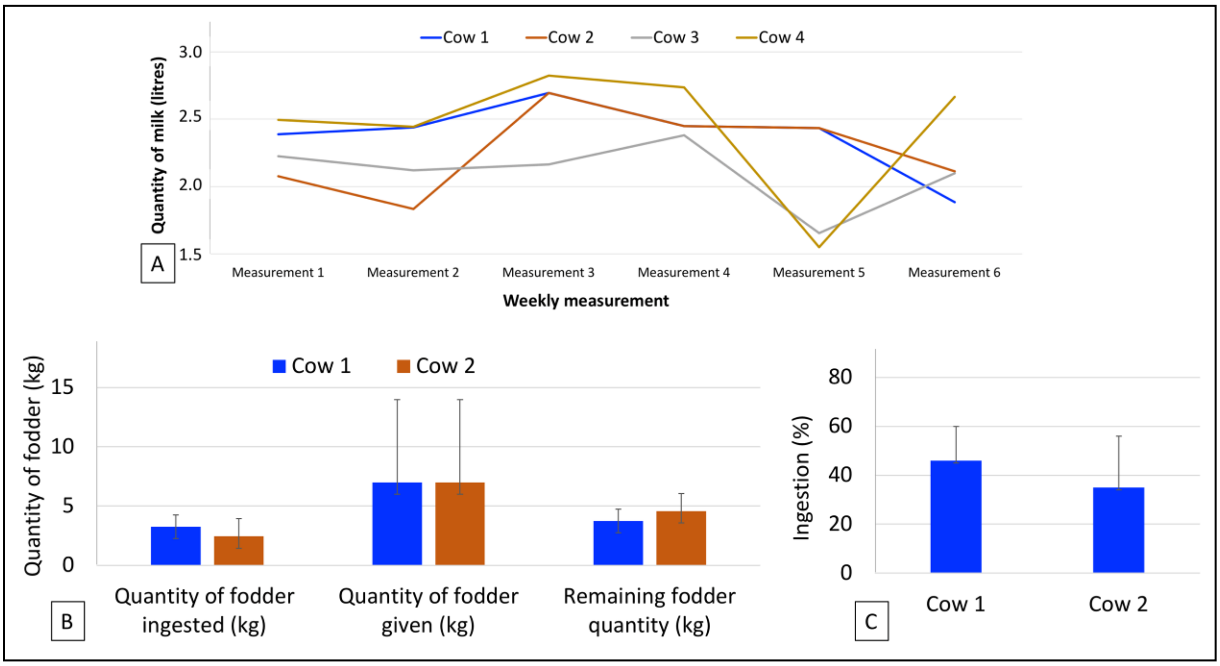

Figure 1: Evolution of the milk production of cows (A) and corn silage feed intake (B and C).

III. Discussion

1. ASMC chopper efficiency

The length of the leaves is much greater than that of the stems whatever the crops. This could be due to the difference in stiffness of the leaves and stems, with stronger stems benefiting from a cleaner, finer cut and leaves tending to curl at the blade. In addition, the lengths obtained are longer than those found in the literature. Forage should be chopped into small pieces of 1-1.5 cm (Ikare, 2015), 0.71-1.42 cm (Denoncourt, 2002), 5-15 cm (Savoie *et al.*, 1998) and 1-2 cm (Brunschwig *et al.*, 2006). However, the chopping tool used in their study included a forage harvester which is industrial made. According to Legarto (2000), the chopped forage must have a length that allows for good compaction and is sufficient for chewing. As far as we are concerned, the size of the pieces of forage did not affect the silage process. The labor time obtained indicates that a farmer using the chopper can cut more than 3,000 kg of fresh forage in three (03) hours during one day working time.

2. Nutritive value of cereal plants before ensiling

The mineral contents of crops are 7.32 ± 0.47%, 6.44 ± 0.12% and 9.55 ± 0.49% for maize, sorghum and millet respectively. The results for maize are similar to those of Nantoumé *et al.* (2000) who found 8%, but their levels for sorghum and millet are much higher than results in current study. These levels are 10.3% for sorghum and 15.7% for millet. According to Mongodin and Rivière (1965), the mineral matter of plants varies according to the plant species and the vegetative stage.

The crude proteins contents of the crops are 11.07 ± 0.95% for maize, 6.96 ± 0.85% for sorghum and 7.83 ± 1.02% for millet. The current results showed higher crude proteins content than what found by Kiéma *et al.* (2008) who reported 3.8%, 3.9% and 5.6% for maize, sorghum and millet, respectively. This could be explained by the method of preservation and the vegetative stage at which the forage was cut. In our study, the forage was cut at the early heading stage and dried in the laboratory in the shade, while in theirs it was crops residues. The same is true for other authors such as Nantoumé *et al.* (2000) who found 2.2%, 3.3% and 3.9% respectively for maize, sorghum and millet. However, our results are close to those of Arrigo *et al.* (2012) and Drapeau *et al.* (2002) who found 8.6% and 13.6% crude proteins content of maize, respectively. The work of Black *et al.* (1980) showed a nitrogen content ranging from 6.2% to 13% for sorghum. However, Leblanc *et al.* (2012) observed that forage nitrogen levels increase with nitrogen fertilization. Our results show that the crude proteins content of maize is higher than that of sorghum and millet. The crude proteins content of maize, sorghum and millet reaches the minimum nitrogen content (7%) threshold below which, the rumen microflora does not function efficiently.

The NDF content is quite high for all crops due to the stage of cutting. The NDF for maize was 63.29 ± 1.15%, significantly lower maize than those of sorghum and millet which were 69.30 ± 0.90 % and 70.39 ± 0.90%, respectively ($p \leq 0.05$). Our results showed high average value than those of Bernardes (2012) who found 64.4% for millet and 65% for sorghum. Fournier (2008) and Bachand (2008) found 54.1 ± 4.6% and 45% NDF for maize, respectively. According to Leblanc *et al.* (2012), an application higher than 120 kg of N/ha would cause a decrease in NDF content.

The ADF content found in this study was also quite high. We found 29.63 ± 0.98% for maize, 36.51 ± 1.21% for sorghum and 39.95 ± 1.35% for millet. Our results fall within the range of values found by Hugo (2018) ranging from 15.35 to 38.04% with an average value of 30.25 ± 5.93% for cereal crops. According to Arab *et al.* (2009), the proportions of NDF and ADF in forages are indications of their nutritive values; NDF shows a fairly accurate estimate of the total fibers in the forage and a prediction of the amount of dry matter intake. Therefore, when the NDF content increases, the feed intake decreases. According to the same author, high ADF content means lower digestibility and metabolized energy for the animal. It can be concluded that silage base-maize has higher crude protein content and lower fiber content (ADF and NDF).

3. Effect of silage on the preservation of the nutritive value of the forage

The comparison between cut raw maize content and silage base-maize showed slightly modification of silage composition. Dry Matter content increased and crude protein content decreased (Table 4). Dry matter increased from 93.19 ± 0.29 to 95.09 ± 1.17% and crude cellulose increased from 33.95 ± 1.35 to 36.65 ± 0.94%. This increase has previously been shown by Andrieu *et al.* (1974) who found 7.2% of increase of the crude cellulose in silage base-maize. According to Demarquilly *et al.* (1973), silage leads to a systematic increase in crud protein and crude cellulose of 4.7% and 8.9% respectively. However, the variation in dry matter obtained in our study is in contrast to that of Dulphy *et al.* (1973) who obtained a decrease in DM content of 3%. Those results could be explained by the stage of cut. Chemical analysis of sorghum showed unchanged composition exception of DM content. According to Baumont *et al* (2011), the total plant wall content may decrease due to the partial hydrolysis of hemicelluloses during fermentation. The high temperatures could explain the increase in the dry matter content of the forage. For millet, we observed also an increase of the DM content.

4. Feed intake

Our study showed a low maize silage intake of 46% for cow 2 and 35% for cow 3. Our results were very low compared with those found in study by Salgado (2003). This author found an intake rate of 90% for maize silage with Holstein cows. This could be explained by the forage distribution period (June 11 - July 11) which was at the beginning of the rain season. The development of rough grazing may have had a negative influence on silage feed intake since the animals already had a source of feed.

5. Effect of silage on milk production

Results show that the maize silage consumed by cows 2 and 3 had regular and increasing milk production compared to the other two cows 1 and 4 that had irregular production (Figure 1A). According to Cuvelier *et al.* (2014), forage DM content, which is important in the dairy cow's diet has a higher content in the silage than in pasture natural grass. This could explain the improvement in milk production because cows 2 and 3 had a higher amount of DM in their diet. In addition, the work of Coulon *et al.* (1994) showed that silage increased milk production by +0.7 kg/day. Silage is still wet forage, it can help to reduce animal dehydration problem in the dry season in a sahelian country like Burkina Faso and increase animal productivity.

CONCLUSION

The chopper is a better tool for chopping maize, millet, sorghum and other cereals and silage from those crops had good nutritive value for silage. The silage did not have a significant effect on the nutritive value of the forage except for the DM of the three crops which increased. The crude cellulose of maize and the crud protein of millet decreased during the ensiling process. Overall, the ensiling process efficiently maintains the nutritive value of the forage, which is essential in the preservation of a forage quality. The maize silage had a positive effect on milk production. The size of the forage chopped with the ASMC chopper does not affect silage quality. In conclusion, ASMC chopper is an appropriate tool for silage making which is a good strategy for livestock feeding system and feed availability in Burkina Faso with conserved feed quality during the dry season.

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