

Demonstration of improved feed trough for efficient feed utilisation by small ruminants in Southern Mali

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Abstract

The ruminant feeding systems of smallholder farmers in mixed crop and livestock systems in Sudano-Sahelian zone of West Africa are characterised by waste. To promote efficient feed use, the use of improved feed trough for small ruminants was demonstrated in Sirakele, Zanzoni and M'Pessoba in Koutiala district in southern Mali in the late (March/April 2019) and early dry (February 2020) seasons. Forty-five farmers were selected randomly in the study sites and were each provided with one improved feed trough which was then compared with the conventional or commonly used feed trough. The quantity of feed offered, and that was wasted during the feeding were measured for six consecutive days, both for the conventional and improved feed troughs. The perceptions of all participating farmers about the technology were documented through response to a series of questions on the potential benefit of the improved feed trough based on the five-point Likert scale. The results showed that the improved feed trough reduced feed waste significantly in all the three sites in both seasons. The percentage of waste in feeding crop residues to sheep and goats using the conventional feed trough were 7.73 ± 0.9 , 26.13 ± 3.3 , and 13.32 ± 1.4 in Sirakele, Zanzoni and M'Pessoba, respectively in the late dry season compared to less than 1 % with the improved feed troughs during the same season in Sirakele and M'Pessoba, respectively while it was 3.33 % in Zanzoni. Feed saved by using improved feed trough gave net return of 13,020, 12,384 and 17,892 FCFA/household/year for Sirakele, Zanzoni and M'Pessoba, respectively. The participating farmers confirmed the benefits of the improved feed trough which are consistent with our results.

Keywords: feed resources, feeding systems, mixed crop-livestock systems, Sahel

1 Introduction

Seasonal feed scarcity, particularly in the dry season, is the norm in Sudano-Sahelian zone of West Africa (Umutoni *et al.*, 2015). The ad-hoc manner of feeding the available feed resources by the smallholder farmers using traditional feed troughs is often characterised by waste as animals eat part, and trample and urinate on the rest (Ayantunde *et al.*, 2008). The extent of feed wastage may vary with seasons, the type of feed, number of animals being fed and the type of feed trough used. Given the feed shortage particularly in the dry season, efficient utilisation of the available feed resources is essential to minimize waste as to feed more animals and to reduce nutrient loss. Efficient feed utilisation is

also critical to cost-effective livestock production systems in the region (Powel *et al.*, 2004) which can be influenced by feed type, animal performance and feeding systems (Diogo *et al.*, 2010).

Improved feed troughs have been designed, tested and evaluated for feeding ruminants (cattle, sheep and goats) by smallholder farmers in Ethiopia, which showed that using improved feed trough saved more than 20 % of the cereal and legume residues offered to cattle compared to the traditional feed trough (Atsbha *et al.*, 2019). The results from the evaluation of the improved feed trough in Ethiopia also showed that it led to a significant increase in the amount of manure collected as the animals spend more time at the feed trough (Atsbha *et al.*, 2019). This technology of improved feed trough looks promising and appropriate for Sudano-

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Sahelian zone of West Africa, where feed scarcity is acute in dry season and there is necessity of using the available feed resources efficiently by reducing wastage. This study was therefore designed to test and demonstrate the effect of improved feed trough on feed utilisation by small ruminants in Koutiala district in southern Mali. The objectives of this study were: (i) to determine the effect of improved feed trough on feed wastage and time spent in feeding small ruminants in Koutiala district in southern Mali across seasons. (ii) to document the perceptions of the participating farmers on the improved feed trough for small ruminants. In addressing these objectives, our hypothesis was that feed wastage depends on type of trough and the quantity of feeds offered.

2 Materials and Methods

2.1 Study sites

The study was undertaken in M’Pessoba, Sirakele, and Zanzoni villages in Koutiala district (“Cercle”) in southern Mali (Fig. 1). M’Pessoba is a village in the rural commune of M’Pessoba, while Sirakele and Zanzoni are villages in the rural commune of Songoua and Fakolo, respectively. All the study sites are less than 50 km north of Koutiala. The dominant farming system in the study sites is mixed crop-livestock with over 90 % of the smallholder farmers rearing sheep and goats which are important for livelihood strategies in poor rural areas of Mali (Ayantunde *et al.*, 2019). The feeding systems are characterised by free grazing of the ruminants in the dry seasons while in the wet season, the grazing is controlled to avoid damage to crops by the animals (Ayantunde *et al.*, 2019). On return from grazing particularly in the dry seasons, animals ate offered supplementary feeds, mainly crop residues such as sorghum and maize straw, groundnut haulm and cowpea hay. The supplementary feeds are often placed on the floor or in a small conventional or commonly used feed trough (Picture 2) and this is associated with feed wastage as animals trample and or urinate on part of the feed. The project intervention communities are in the “Zones of Influence” of United States Agency for International Development (USAID) Program in Mali, the donor for Africa RISING project under which the present study was conducted. The overall goal of the Africa RISING project is to create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

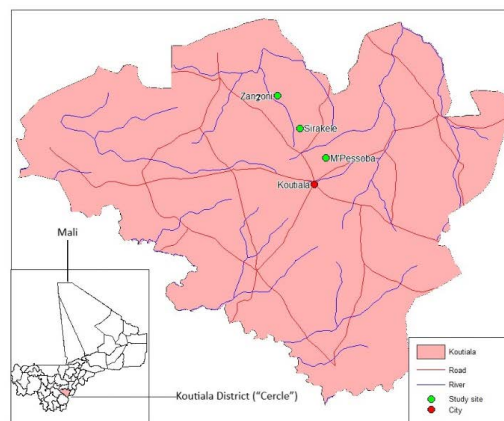


Fig. 1: Map of the study sites in Koutiala district, Mali.

2.2 Study design

Twenty (20) farmers in Sirakele, fifteen (15) farmers in Zanzoni and ten (10) farmers in M’Pessoba based on ownership of at least 6 sheep and or goats, willingness to participate in the study, and previous involvement in Africa RISING project activities. At least two (10 %) of the selected farmers in each study site were female. Each farmer was provided with one improved feed trough made with woods and covered with sorghum stem (Picture 1), which was then compared with the conventional or commonly used feed trough (Picture 2). The conventional or commonly used feed troughs are in different forms as farmers in our study sites use different available materials like broken clay pot, cut plastic can (Picture 2), disused household plastic or metallic bowl, and broken wooden platform as feed trough for small ruminants. What is common with these traditional feed troughs is that they are not constructed and small in size compared to the improved feed trough which was constructed as in this study. The dimensions of the improved feed trough were: height from the ground to the feeding base 25 cm, height of the feeding area 25 cm, length of the feeding area 120 cm, width of the feeding area 80 cm, and height from feeding base to the roof 140 cm. There could be some variation from these dimensions particularly in terms of length, width and height from the ground depending on the local artisanal who constructed the trough. The improved feed trough made with locally available materials cost about 15,000 FCFA (about USD 25). The quantity of feed offered (both in the morning and evening) and that was wasted during the feeding were measured for six consecutive days using an electronic balance with maximum weight of 10 kg (10 g) both for the conventional and improved feed troughs in the 3 study sites in the late (March/April 2019) and early dry (February 2020) seasons. The quantity and types of feed offered depended on the management of individual farmer. Regard-

ing the number of animals that feed from each trough, the farmers divided the flock into two with half eating from each trough. Wastage is the proportion of the feed quantity wasted at the end of feeding divided by the quantity offered, which was then multiplied by 100 to express it as a percentage.



Pic. 1: Improved feed trough for small ruminants constructed with locally available materials in Sirakele with sheep and goats eating groundnut haulms (Photo credit: Théophile Dembele; AMEDD, Mali).



Pic. 2: Conventional feed trough for small ruminants in Sirakele (Photo credit: Théophile Dembele; AMEDD, Mali).

The feed offered were mainly crop residues such as groundnut haulms, cowpea hay, bush hay and leaves from trees such as *Pterocarpus erinaceus*, *Ziziphus mauritiana*, which were placed in the feed troughs as bundle. The amount of time spent in feeding sheep and goats (bringing back dispersed feed, keeping animals to feed comfortably) was also measured using a stopwatch which recorded the time spent right from the beginning to the end of each feeding session. The net return of both types of feed trough was estimated from the revenue from the feed saved and manure collected minus the cost of the feed trough in each study site. The revenue from feed saved was estimated from the quantity of feed saved for all seasons which was then multiplied by average price of crop residues (cowpea hay, groundnut

haulms, bush hay and straws) across seasons according to Ayantunde *et al.* (2014). The revenue from manure was estimated from quantity of manure dry matter collected multiplied by the price of kg of air-dried manure which was about 100 FCFA per kg DM. The cost of conventional or commonly used feed trough varied from 350 to 1000 FCFA while the cost of improved feed trough was 15,000 FCFA. The improved feed trough can last for at least 3 years which meant that the cost per year was 5,000 FCFA. A semi-structured questionnaire was also administered to individual participating farmers to document their perceptions about the benefits of the technology to efficient feeding systems. The participating farmers responded to a series of questions on the potential benefit of the improved feed trough (Table 4) based on the five-point Likert scale (Likert, 1932), which could be “completely disagree” (1), “disagree” (2), “neither disagree or agree” (3), “agree” (4), or “completely agree” (5). The improved feed troughs are two sided and can be used by up to 12 sheep and goats.

2.3 Data analysis

Data analysis was performed with SAS (SAS, 1987) using Means Procedures for descriptive statistics while GLM Procedures was used to assess the effect of types of feed trough, season and community on the feed offered, time spent feeding the animals, percentage of wastage and net return. Mixed effect model was used with season and community as random variables while feed trough type was the fixed variable. Unless otherwise specified, the level of significance was set at $P < 0.05$.

3 Results

3.1 Profiles of the participating farmers

The participating farmers in this study were 15 males and 5 females in Sirakele, 13 males and 2 females in Zanzoni, and 5 males and 5 females in M’Pessoba. The average age of the participating farmers was 50.7, 56.0 and 35.4 years in Sirakele, Zanzoni and M’Pessoba, respectively during the data collection in the late dry season (March/April 2019). The average age (mean \pm standard error) of the participating farmers in the early and late dry seasons was similar between Sirakele and Zanzoni; while at M’Pessoba the farmers were significantly younger compared to the other two sites (Table 1).

The slight differences (though statistically insignificant) in age of the participating farmers between the two seasons were due to five farmers in all the study sites that dropped out of the study and were replaced. The lower age of participants in M’Pessoba could be attributed to participation

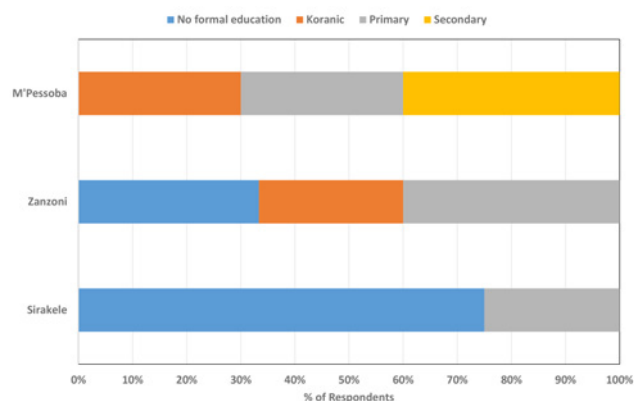
Table 1: Age and livestock assets of participating farmers in Sirakele, Zanzoni and M’Pessoba in Koutiala district in Southern Mali (mean \pm standard error)

Village	Age (year)*	Cattle *	Sheep *	Goat *
<i>Late dry season (March / April 2019)</i>				
Sirakele (n=20)	50.7 \pm 2.96 ^a	3.9 \pm 1.6 ^a	12.5 \pm 1.2 ^a	12.5 \pm 1.7 ^a
Zanzoni (n=15)	56.0 \pm 2.9 ^a	1.0 \pm 0.9 ^b	6.4 \pm 1.1 ^b	2.9 \pm 1.0 ^b
M’Pessoba (n=10)	35.4 \pm 3.3 ^b	4.0 \pm 1.6 ^a	4.2 \pm 1.6 ^b	2.6 \pm 1.4 ^b
<i>Early dry season (February 2020)</i>				
Sirakele (n=20)	51.3 \pm 2.9 ^a	2.1 \pm 0.9 ^a	12.9 \pm 0.9 ^a	12.3 \pm 1.3 ^a
Zanzoni (n=15)	54.4 \pm 2.6 ^a	1.0 \pm 0.4 ^a	9.9 \pm 1.0 ^a	4.2 \pm 1.3 ^b
M’Pessoba (n=10)	36.3 \pm 3.3 ^b	1.4 \pm 0.6 ^a	3.9 \pm 1.6 ^b	1.0 \pm 0.2 ^c

^{a,b} Values followed by different superscripts for the same variable are statistically significant ($P < 0.05$).

* The comparison between seasons for each site showed that there was no significant difference in age of the respondents and for herd size for cattle, and flock size for sheep and goat except for sheep in Zanzoni.

of more young people in the study which accounted for half of the participants. More than 90 % of the participants in the study sites were crop and livestock farmers while the remaining participants were engaged in livestock husbandry only. Seventy-five percent of the participating farmers in Sirakele had no formal education (Fig. 2) whereas 40 % of the farmers in M’Pessoba had secondary school education. Generally, the farmers had more sheep and goats than cattle (Table 1) in all the intervention communities. Farmers in Sirakele had significantly higher sheep and goat than those in Zanzoni and M’Pessoba.

**Fig. 2:** Education level of participating farmers in the intervention communities.

3.2 Benefits of improved versus conventional feed troughs and partial cost benefit analysis

The results of the six days monitoring of the use of the conventional and improved feed troughs (Table 2) showed that the improved feed trough reduced feed waste significantly in all the three study sites (Sirakele, Zanzoni and

M’Pessoba) in both late and early dry seasons. The quantity of feed wasted was significantly higher ($P < 0.05$) with the use of conventional feed trough than for the improved feed trough. The percentage of wastage in feeding crop residues to the animals using the conventional feed trough were 7.73, 26.13, and 13.32 in Sirakele, Zanzoni and M’Pessoba, respectively in the late dry season compared to less than 1 % with the improved feed trough during the same season in Sirakele and M’Pessoba, respectively while it was 3.33 % in Zanzoni. These results indicated about 7 %, 23 % and 12 % feed saved in Sirakele, Zanzoni and M’Pessoba, respectively by using improved feed trough (Table 2). Similar trends were observed in the early dry season. Across communities, the feed wastage for conventional feed trough was significantly higher in Zanzoni than in Sirakele and M’Pessoba in the late dry season but there were no significant differences in the percentage feed wastage across communities for improved feed trough in both late and early dry seasons. The results also showed that farmers spent slightly less time in feeding the animals with the improved feed trough than using conventional feed trough but the differences were insignificant in both seasons. Significantly more feed was offered in the early dry season for both types of feed troughs than in the late dry season which reflects availability of more feed resources particularly the crop residues.

The net return for the improved feed trough was significantly higher than for the conventional feed trough in all the study sites (Table 3). Feed saved by using improved feed trough gave revenue of 13,020, 12,384 and 17,892 FCFA/household/year for Sirakele, Zanzoni and M’Pessoba, respectively (Table 3). The other source of revenue was from manure collected while the main cost was for acquisition of feed trough. The average quantities of manure

Table 2: Feed offered, quantity wasted, and time spent feeding small ruminants across seasons with the use of conventional and improved feed troughs in Sirakele, Zanzoni and M'Pessoba in Koutiala district in Southern Mali (Mean \pm standard error)

Variable	Sirakele (n=20)		Zanzoni (n=15)		M'Pessoba (n=10)	
	Conventional	Improved	Conventional	Improved	Conventional	Improved
<i>Late dry season (March / April 2019)</i>						
Number of animals [†]	9.5 \pm 0.2	9.5 \pm 0.2	4.4 \pm 0.1	4.4 \pm 0.1	3.2 \pm 0.2	3.2 \pm 0.2
Quantity of feed offered (g DM/day)	3000 \pm 150	3000 \pm 150	1000 \pm 50	1000 \pm 50	2600 \pm 305	2600 \pm 305
Quantity wasted (g DM/day)	232.0 \pm 27.8 ^a	20.8 \pm 7.6 ^b	261.3 \pm 33.0 ^a	33.3 \pm 10.0 ^b	346.5 \pm 32.5 ^a	22.6 \pm 16.0 ^b
% of feed wasted	7.7 \pm 0.9 ^a	0.7 \pm 0.3 ^b	26.1 \pm 3.3 ^a	3.3 \pm 1.0 ^b	13.3 \pm 1.4 ^a	0.9 \pm 0.8 ^b
Time spent feeding (min/day)	30.6 \pm 0.6	29.1 \pm 0.3	30.0 \pm 0.8	28.1 \pm 0.7	34.2 \pm 1.1	32.9 \pm 1.1
<i>Early dry season (February 2020)</i>						
Number of animals [†]	8.5 \pm 0.2	8.5 \pm 0.2	5.5 \pm 0.1	5.5 \pm 0.1	2.0 \pm 0.1	2.0 \pm 0.1
Quantity of feed offered (g DM/day)	3650 \pm 197	3800 \pm 171	2400 \pm 221	2800 \pm 200	3500 \pm 619	4700 \pm 715
Quantity wasted (g DM/day)	233.8 \pm 40.0 ^a	7.8 \pm 3.9 ^b	177.0 \pm 27.6 ^a	3.0 \pm 1.8 ^b	269.0 \pm 54.0 ^a	8.0 \pm 3.1 ^b
% of feed wasted	6.4 \pm 1.3 ^a	0.2 \pm 0.1 ^b	7.4 \pm 0.9 ^a	0.1 \pm 0.1 ^b	7.7 \pm 0.9 ^a	0.2 \pm 0.1 ^b
Time spent feeding (min/day)	23.2 \pm 0.9 ^a	18.6 \pm 0.7 ^b	23.6 \pm 0.7	20.5 \pm 0.8	30.8 \pm 2.2	27.5 \pm 2.3

^{a,b} Values followed by different superscripts for the same variable on the same row for each study site are statistically significant ($P < 0.05$).

[†] Small ruminants only.

Table 3: Partial cost and benefit analysis of conventional and improved feed troughs in the study sites in Koutiala district in southern Mali (Mean \pm standard error; FCFA /household / year).

Variable	Sirakele		Zanzoni		M'Pessoba	
	Conventional	Improved	Conventional	Improved	Conventional	Improved
Revenue from feed saved	0 ^a	13,020 \pm 54 ^b	0 ^a	12,384 \pm 48 ^b	0 ^a	17,892 \pm 86 ^b
Revenue from manure collected	1,834 \pm 7 ^a	3,680 \pm 28 ^b	1,650 \pm 12 ^a	2,500 \pm 16 ^b	1,920 \pm 27 ^a	4,870 \pm 32 ^b
Gross return	1,834 \pm 7 ^a	16,700 \pm 58 ^b	1650 \pm 12 ^a	14,884 \pm 52 ^b	1,920 \pm 27 ^a	22,762 \pm 92 ^b
Feed trough cost ¹	750 \pm 10 ^a	5,000 \pm 0 ^b	750 \pm 15 ^a	5,000 \pm 0 ^b	800 \pm 12 ^a	5,000 \pm 0 ^b
Total cost	750 \pm 10 ^a	5,000 \pm 0 ^b	750 \pm 15 ^a	5,000 \pm 0 ^b	800 \pm 12 ^a	5,000 \pm 0 ^b
Net return	1,084 \pm 8 ^a	11,700 \pm 42 ^b	900 \pm 11 ^a	9,884 \pm 28 ^b	1,120 \pm 18 ^a	17,782 \pm 64 ^b

^{a,b} Values followed by different superscripts for the same variable on the same row for each study site are statistically significant ($P < 0.05$, Duncan's Multiple Range Test).

¹ The cost of conventional feed trough varied from 350 to 1000 FCFA while the cost of improved feed trough was 15,000 FCFA. The improved feed trough can last for at least 3 years which meant that the cost per year was 5,000 FCFA.

collected per study site in both seasons were 52.44, 42.5 and 70.08 kg DM for Sirakele, Zanzoni and M'Pessoba, respectively. The results showed that the improved feed trough is economically viable for smallholder farmers in mixed crop and livestock production systems in Sudano-Sahelian zone of Mali. The participating farmers in M'Pessoba were highly committed in collecting the manure immediately after the animals finished feeding as they use this for home gardens whereas in Sirakele and Zanzoni, the farmers were far less committed to collecting the manure. Essentially, there was significant loss of manure in Sirakele and Zanzoni.

3.3 Gender group in feeding animals with different feed troughs across seasons

Male adults were largely responsible for feeding the animals in all the intervention communities and across seasons (Fig. 3a and b). Both female adults and boys were also involved in feeding the animals in all the communities in both seasons. There was no report of the involvement of girls in feeding the animals with either the traditional or improved feed trough in all the communities. The results were similar for both the traditional and improved feed troughs across seasons in all the communities.

3.4 Perceived benefits of the improved feed trough

After the 6 days monitoring of the use of the conventional and improved feed troughs, the farmers were asked individu-

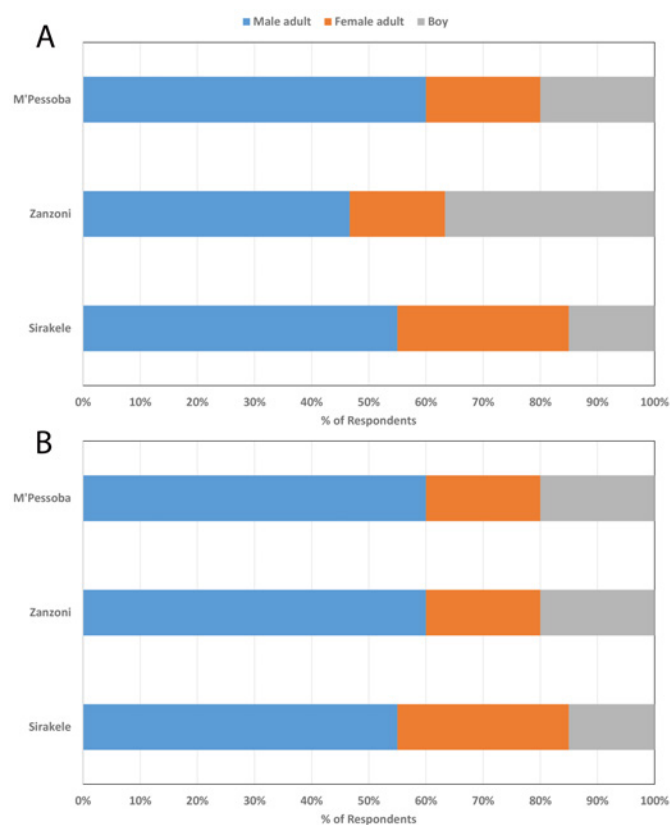


Fig. 3: Gender group of those feeding small ruminants in A. the late dry season (March/April 2019) and B. in the early dry season (February 2020) in the intervention communities (Sirakele $n=20$; Zanzoni $n=15$; M'Pessoba $n=10$).

ally to respond to a series of statements on the perceived benefits of the improved feed trough in each season of data collection. The statements presented in a semi-structured questionnaire are included in Table 4 as well as the response of the participating farmers which could be completely disagree, disagree, neither disagree or agree, agree or completely agree. Across seasons and in all the study sites, the farmers strongly agreed (100%) that there is less feed waste with the improved feed trough and that it reduces feed contamination. They also strongly agreed that the improved feed trough is comfortable for the animals to eat from and that the benefits outweigh the costs in the long run. Nearly all the participating farmers (83%) agreed that they would invest in constructing the improved feed troughs soon. They also strongly agreed that the animals tend to eat more (80%) with the improved feed trough which can be confirmed by less quantity of leftover compared to the traditional feed trough. They disagreed strongly (87%) that the improved feed trough is only beneficial for households with high flock size and that it is difficult for women to use.

4 Discussion

The results of significantly higher waste in feeding crop residues to the animals using the conventional or commonly used feed trough than in using improved feed trough in the study sites for both late and early dry seasons confirmed that the traditional feeding systems in West Africa Sahel are characterised by a high level of feed wastage (Ayantunde *et al.*, 2008). The results also showed that a simple technology like improved feed trough constructed with locally available materials can enhance feed use efficiency. The quantity of feed saved through improved feed trough were 91.44 and 79.32 kg DM per household in late and early dry seasons, respectively which can be used to feed more or better sheep and goats. For cattle, the reduction in feed waste reported by Atsbha *et al.* (2019) is much higher than our results which is expected in view of significantly higher feed offer to cattle. Reducing feed waste will also reduce the feed cost incurred for livestock production. This is particularly important for livestock enterprise like sheep fattening and smallholder dairy production in peri-urban areas West Africa Sahel where livestock feed can be expensive and efficiency in feed utilisation is critical to a profitable enterprise (Nantoume *et al.*, 2000; Graef *et al.*, 2008; Millogo *et al.*, 2008; Ayantunde *et al.*, 2014). The participating farmers in the study confirmed this main advantage of the improved feed trough that it led to significant reduction in feed waste and this can facilitate the adoption of the technology as the benefit is obvious to the smallholder farmers.

Our results that female adults were also involved in feeding the animals in addition to male adults and boys in the study sites agree with results of Amole *et al.* (2020) that management of small ruminants in West Africa Sahel, particularly feeding and watering, are done by women. Generally, women play significant roles in rearing of small ruminants in West Africa (Bamigboye *et al.*, 2013; Tamini *et al.*, 2014; Ayantunde *et al.*, 2008) and they are largely responsible for decisions on income from sale of sheep and goats in contrast to decisions on income from sale of cattle which are dominated by male adults (Amole *et al.*, 2020). As women and youth are key actors in feed value chain in West Africa as reported by Konlan *et al.* (2018), strengthening their participation will provide them with better opportunities in the feed value chain (Balehegn *et al.*, 2020).

The participation of the youths in M'Pessoba study site as demonstrated by the significantly lower age of the participating farmers compared to the other two sites suggest that the technology can contribute to creation of employment opportunity for the youths through construction of the improved feed trough for small ruminants. Given the large number of unemployed youths in West Africa and the inability of the

Table 4: Response to the perceived benefits (Percent) of the improved feed trough compared to the conventional feed trough across seasons. The percentage of the respondents with the modal score is indicated in parenthesis after each score.

Statement	Sirakele (Mode)	Zanzoni (Mode)	M'Pessoba (Mode)
<i>Late dry season (March/April 2019)</i>			
1. There is less feed waste with the improved feed trough compared to the conventional practice	5 (100 %)	5 (100 %)	5 (100 %)
2. The improved feed trough reduces feed contamination with sand, feces, urine etc.	5 (90 %)	5 (100 %)	5 (100 %)
3. The improved feed trough is comfortable for the animal to eat from	5 (90 %)	5 (100 %)	5 (90 %)
4. The benefit of the improved feed trough outweighs the cost	5 (100 %)	5 (100 %)	5 (90 %)
5. I will invest in constructing improved feed trough for my animals	4 (80 %)	5 (73 %)	5 (80 %)
6. The animals eat more with the improved feed trough	5 (75 %)	5 (67 %)	5 (80 %)
7. The improved feed trough reduces time spent on feeding the animals	4 (80 %)	4 (73 %)	5 (90 %)
8. The improved feed trough is only beneficial to those who have many animals	2 (85 %)	2 (93 %)	2 (80 %)
9. The improved feed trough is difficult for women to use	1 (90 %)	1 (100 %)	1 (100 %)
10. The improved feed trough will last much longer than the conventional feed trough	4 (85 %)	3 (73 %)	3 (80 %)
<i>Early dry season (February 2020)</i>			
1. There is less feed waste with the improved feed trough compared to the conventional practice	5 (100 %)	5 (100 %)	5 (100 %)
2. The improved feed trough reduces feed contamination with sand, feces, urine etc.	5 (100 %)	5 (93 %)	5 (100 %)
3. The improved feed trough is comfortable for the animal to eat from	5 (100 %)	5 (87 %)	5 (90 %)
4. The benefit of the improved feed trough outweighs the cost	5 (85 %)	5 (93 %)	5 (80 %)
5. I will invest in constructing improved feed trough for my animals	4 (80 %)	5 (93 %)	5 (90 %)
6. The animals eat more with the improved feed trough	5 (80 %)	5 (87 %)	5 (90 %)
7. The improved feed trough reduces time spent on feeding the animals	4 (80 %)	4 (93 %)	5 (80 %)
8. The improved feed trough is only beneficial to those who have many animals	2 (90 %)	2 (87 %)	2 (90 %)
9. The improved feed trough is difficult for women to use	1 (100 %)	1 (100 %)	1 (100 %)
10. The improved feed trough will last much longer than the conventional feed trough	4 (90 %)	3 (93 %)	3 (90 %)

(Likert Scale: 1= Completely disagree; 2= Disagree; 3=Neither disagree or agree; 4=Agree; 5=Completely agree) by the participating farmers in the intervention communities (Sirakele n=20; Zanzoni n=15; M'Pessoba n=10).

formal sector to provide jobs for them, the informal sector, particularly agriculture sector, will remain a major employer of the less educated youths (Fox *et al.*, 2016). Therefore, developing agricultural technologies that can provide employment opportunities for the youths can contribute to the improved livelihood of the rural communities in the region. The significant high net return observed for the improved

feed trough suggests that it can be a viable venture for the youths in rural areas. The net return from the use of improved feed trough could be higher with better collection of manure by the participating farmers which could have resulted in more revenue from manure collected. The loss of manure from feeding ruminants at home is a challenge to manure collection to fertilize the crop field (Ayantunde *et*

al., 2018) which is often rationale for corralling grazing ruminants on the crop field. For instance, by corralling the animals on the cropland, both manure and urine are returned to the soil, and losses during manure storage and transportation are reduced (Ayantunde *et al.*, 2018). The net return could also be higher by reducing the cost of the feed trough, particularly the improved feed trough which in this study was 15,000 FCFA as this cost may be location-specific depending on the local materials used and the cost of artisan who constructs the feed trough.

The responses of the participating farmers to the statements on the perceived benefits of the improved feed trough compared to the conventional feed trough are consistent with our results from the monitoring of the use of the two types of trough in the study sites. The positive perception of the improved feed trough can facilitate adoption of the technology. The low cost of the technology which is about 15,000 FCFA as the materials for its construction are locally available can further enhances the adoption. The cost of constructing the improved feed trough can be recovered within 6 months from the quantity of feed that will be saved from a flock size of least six sheep and goats, which should provide a further incentive for the adoption of the technology by resource-poor farmers. This study has demonstrated that a simple low-cost technology can significantly improve efficient utilisation of feed by small ruminants thereby enhancing livestock productivity in West Africa Sahel.

5 Conclusions

The main conclusion from this study on the use of the improved feed trough in Sirakele, Zanzoni and M’Pessoba in Koutiala district in southern Mali in the late and early dry seasons is that it reduces feed waste significantly thereby improving efficient utilisation of feed by small ruminants. Economically, the technology is profitable as the farmers made a net return of at least 12,000 FCFA/household/year. The responses of the participating farmers on the perceived benefits of the improved feed trough in the study sites are consistent with our results. This positive perception of the improved feed trough can facilitate adoption of the technology. Besides, the low cost of constructing the improved feed trough will also facilitate adoption. From the significant reduction in feed wastage by using the improved feed trough, it can be implied that the technology increases feed use efficiency. This study has demonstrated that a simple low-cost technology can significantly improve efficient utilisation of feed resources by small ruminants thereby enhancing livestock productivity in West Africa Sahel.

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Conflict of interest

The authors declare that there is no conflict of interest.

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