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SHORT NOTE [NOTA CORTA]

POTENTIAL USE OF CROP RESIDUES AS LIVESTOCK FEED RESOURCES UNDER SMALLHOLDER FARMERS CONDITIONS IN BALE HIGHLANDS OF ETHIOPIA

[POTENCIAL DE LOS RESIDUOS DE COSECHA COMO ALIMENTO PARA RUMIANTES BAJO CONDICIONES DE PEQUEÑOS PRODUCTORES EN ETIOPÍA]

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SUMMARY

The study was conducted in Sinana Dinsho district of Bale Highlands, which has bimodal (Sinana sub district) and mono modal (Dinsho sub district) rainfall patterns. Data on available crop residues and feeding practices in the district were obtained in a baseline survey involving 195 farmers to generate information on the importance of crop residues available for animal feeding in the district. Nutrient content of major crop residues of wheat, barley, emmer wheat, linseed, field pea, faba bean and maize were determined. The availability of each type of crop residues varied ($P < 0.05$) between Sinana and Dinsho sub districts. Season of harvest had no significant effect ($P > 0.05$) on crude protein (CP), neutral detergent fiber (NDF) contents and *in vitro* dry matter digestibility (IVDMD) of the crop residues in Sinana. The IVDMD of wheat straw was lower ($P < 0.05$) than that of barley and emmer wheat. Hemicellulose content of cereal crop residues was higher ($P < 0.001$) than that of pulses and linseed. In general, the crop residues were low in CP and IVDMD, but high in fiber content, and thus require some degree of supplementation or treatment to support reasonable livestock performance.

Keywords: Crop residues, chemical composition, IVDMD, Bale highlands.

RESUMEN

El estudio se realizó en región Bale de Etiopía, la cual tiene una patrón de lluvias de distribución bimodal (Sub distrito Sinana) y mono modal (sub distrito Dinsho). Se obtuvo la información sobre residuos de cosecha y prácticas de alimentación en el distrito. Se encuestó a 195 productores para generar información sobre la importancia de los residuos de cosecha en la alimentación animal. Se analizó el contenido de nutrimentos de los principales residuos disponibles para alimentación animal (trigo, cebada, frijoles, maíz, linaza, chícharo). La disponibilidad de los residuos varió entre sub distritos ($P < 0.05$). La estación de cosecha no tuvo efecto ($P > 0.05$) sobre los contenidos de proteína cruda (PC), fibra detergente neutra y la digestibilidad *in vitro* de la materia seca (IVDMS). La IVDMS del trigo fue menor al de la cebada ($P < 0.05$). El contenido de Hemicelulosa de los residuos de cereales fue mayor al de los residuos de frijoles y linaza ($P < 0.001$). En general, los residuos de cultivos son bajos en PC e IVDMS, pero altos en fibra. In general, the crop residues were low in PC and IVDMS, pero altos en fibra y requerirían de algún tipo de suplementación para sostener la production animal.

Palabras clave: Subproductos, composición química, digestibilidad *in vitro.*

INTRODUCTION

The highlands of Ethiopia are characterized by mixed crop livestock farming systems where the crop and livestock sub-systems complement each other (Getachew et al,. 1993). They are inhabited by large human and livestock population where smallholder farmers cultivate variety of crops and rear different livestock species. The area of land allocated to grazing in the highlands has been progressively declining through time due to expansion of cultivation. As a result, crop residues have become one of the major feed sources for livestock, particularly during the dry period (Daniel, 1988). Generally, quality and quantity of crop residues vary markedly with altitude, rainfall, soil type, and cropping intensity. The progressive

expansion of wheat-based monocropping in Bale highlands has raised the importance of wheat straw and stubble as animal feed by replacing natural grazing areas, which were encroached for cultivation of cereal crops. However, there is information gap with regard to the degree of importance of crop residues as livestock feed resources in the highlands of Ethiopia in general, and in Sinana Dinsho district of Bale highlands in particular. Thus, the objectives of the study were to generate baseline data on the quantity and quality of crop residues available for animal feeding in the study area.

MATERIAL AND METHODS

Study area and sampling

The study was conducted in Sinana Dinsho district of the Bale highlands, Ethiopia. Dinsho sub district has a mild sub-tropical highland climate with annual mean minimum and maximum temperature of 2 ^{o}C and 20 ^{o}C, respectively. The rainfall distribution pattern of Dinsho area is characterized by one eight- month rainy season from late March to October. On the other hand, the rainfall in Sinana sub district is bimodal with the main rainy season from August to December and the small rainy season from March to July. The temperature in Sinana sub district ranges between 9.4 °C and 21.2 °C.

A stratified multistage sampling technique was employed to select the sampling unit. The district was first stratified into two 'recommendation domains' based on the rainfall pattern and cropping system. A list of households keeping livestock was prepared and used to construct a sampling frame. Finally, a total of 195 households (131 in Sinana and 64 in Dinsho) were selected based on the proportion of the number of households owning livestock and the size of the sub districts'.

Quantification of crop residues

Informal interviews were conducted in the district to enable develop a semi-structured questionnaire that was pre-tested with ten farmers to collect information on availability, type, area coverage, yields across seasons, feeding systems and conservation practices of crop residues. Quantity of dry matter (DM) output from major crop residues was estimated by conversion of grain yields to fibrous residues using multipliers of 1.5 for wheat, barley and emmer wheat, and 1.2 for field pea, faba bean, and linseed (FAO, 1987). For estimation of stover DM output from maize, a multiplier of 2 was employed as proposed by de Leeuw *et al.* (1990). About 10% of the yield of crop residues were considered as wasted either during feeding process or used for other purposes or both (Adugna and Said, 1994). Utilizable average DM yield of stubble grazing was estimated to be 0.5 t/ha per annum (FAO, 1987).

Feed sample preparation and chemical analysis

Feed samples were collected and oven-dried at 65°C for 72 hours and ground to pass through a one-millimeter sieve. Feed samples were analyzed for DM, nitrogen (N) and ash contents according to AOAC (1990). Crude protein (CP) was determined as N x 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by the methods of Van Soest *et al.* (1991). Sulfite and α -amylase were not used as reagents in the determination of NDF. Ash corrected NDF was determined by overnight burning of the NDF in a furnace at 550 °C. Sulfuric acid lignin was determined on the ADF residue. Hemicellulose and cellulose contents were calculated as the differences between NDF and ADF, and ADF and ADL, respectively. The Tilley and Terry method as modified by Van Soest and Robertson (1985) was used to determine *in vitro* DM digestibility (IVDMD).

Statistical analysis

Data were analyzed using the statistical software, Minitab, version 12.0 (Minitab, 1998). Means with significant differences at $P < 0.05$ were compared with each other using the Tukey pair-wise comparison procedure. The following analysis of variance model was used for data analysis.

$Y_i = \mu + l_i + e_{ij}$, where;

Y_i = quality and quantity of feed available
μ = overall mean
l_i = the effect of the i^{th} location
e_{ij} = random error

RESULTS

Available crop residues

The principal crop residues available for livestock feeding in the study area included residues from cereals (maize, wheat, barley and emmer wheat), pulses (field pea and faba bean), and linseed. The available quantity of each type of crop residue varied significantly ($P < 0.05$) between Sinana and Dinsho sub districts (Table 1). In Dinsho, barley straw was almost the sole crop residue available for livestock feeding, and even then, available straw from barley in Sinana was higher ($P < 0.05$) than that in Dinsho. Importance of crop residues in Dinsho sub district is low, since wheat, linseed and pulses are not widely cultivated, and thus straws of these crops are not

commonly used as livestock feed compared to Sinana sub district. Hence, livestock in Dinsho sub district depend mostly on grazing of natural pasture both during the wet and dry seasons, whereas crop residues are as important as natural pasture in Sinana sub district.

Feeding systems practiced

Crop residues are primarily used for the feeding of draught animals by about 85 and 69% of the farmers in Sinana and Dinsho sub districts, respectively (Table 2). The practice of feeding livestock with straw in the morning and evening around homesteads is a common practice, especially during the rainy season in Sinana sub district. By-products of oilseeds are mixed with straw and other available supplements at household level such as residue of local brewing practices (*atela*) to feed livestock. Crop residues were the main feed source for livestock during the dry period in 81.4% of the cases from early January to April when pasture from grazing area cease to provide reasonable quantity of feed in Sinana sub district. About 81.7% of the farmers in Sinana sub district ranked barley straw as the most important crop residue (Table 3). Livestock were allowed to graze crop stubbles, preferably that of barley twice in a year in Sinana and once in a year in Dinsho sub districts. Stubble grazing of cereal crops is practiced after harvest from mid July to late August after the short rainy season in Sinana, and from November to April in both Sinana and Dinsho sub districts.

Table 1. Available crop residues from major crops per household in Sinana and Dinsho sub districts of Bale highlands.

Crop residues	Sinana (N = 131)		Dinsho (N = 64)		Overall (N = 195)	
	Mean ± SE (tonne)	Proportional contribution	Mean ± SE (tonne)	Proportional contribution	Mean ± SE (tonne)	Proportional contribution
Wheat	5.1 ± 0.45[a]	0.563	0.04 ± 0.02[b]	0.021	3.4 ± 0.34	0.507
Barley	2.5 ± 0.20[a]	0.282	1.80 ± 0.25[b]	0.963	2.3 ± 0.16	0.343
Emmer wheat	0.8 ± 0.08	0.087	-	-	0.6 ± 0.06	0.087
Field pea	0.15 ± 0.02	0.017	-	-	0.1 ± 0.02	0.015
Faba bean	0.03 ± 0.01	0.003	-	-	0.02 ± 0.01	0.003
Linseed	0.07 ± 0.02[a]	0.008	0.03 ± 0.01[b]	0.016	0.06 ± 0.01	0.009
Maize	0.4 ± 0.05	0.040	-	-	0.24 ± .04	0.036
Total supply	9.0± 0.61[a]	1.00	1.9 ± 0.25[b]	1.00	6.7± 0.48	1.00

[ab] means with different superscripts within a row are different (P < 0.05); N = number; SE = standard error.

Table 2. Feeding priorities of livestock with crop residues as practiced in Sinana Dinsho district of Bale highlands.

Livestock type	Location	N	Crop residues feeding rank (proportion of respondents)			
			1st	2nd	3rd	4th
Draft oxen	Sinana	125	0.848	0.144	0.008	-
	Dinsho	55	0.691	0.254	0.055	-
	Overall	180	0.800	0.178	0.022	-
Weak animals	Sinana	123	0.106	0.480	0.325	0.089
	Dinsho	55	0.255	0.309	0.436	-
	Overall	178	0.152	0.427	0.360	0.062
Calves	Sinana	116	0.060	0.534	0.336	0.069
	Dinsho	54	0.074	0.481	0.444	-
	Overall	170	0.065	0.518	0.371	0.047
Lactating cows	Sinana	117	0.068	0.641	0.248	0.043
	Dinsho	54	0.074	0.481	0.400	0.018

N = number.

Table 3. Utilization of crop residues as livestock feed in Sinana sub-district of Bale highlands.

Type of crop residue	N	Rank of crop residues as animal feed (proportion of respondents)			
		1st	2nd	3rd	4th
Wheat	130	0.131	0.400	0.377	0.092
Barley	131	0.817	0.176	0.008	-
Emmer wheat	124	-	0.371	0.484	0.145
Pulse	47	-	0.043	0.128	0.830
Maize	60	0.117	0.133	0.150	0.600

N = number of respondents

Chemical composition and *in vitro* dry matter digestibility of crop residues

Chemical composition of crop residues in the district is given in Tables 4 and 5. Barley straw contained relatively higher CP than its stubble in Dinsho sub district. Season of harvest had no effect ($P > 0.05$) on CP content of crop residues in Sinana sub district. The content of CP was not different ($P > 0.05$) for crop residues from various species in Sinana sub district, however, the difference in NDF content of crop residues in Sinana sub district was significant ($P < 0.05$). The NDF content was lower ($P < 0.05$) for faba bean straw, while it was higher ($P < 0.05$) for crop stubbles, particularly for wheat stubble (Table 5). Except that of faba bean straw, the NDF content of all crop residues considered was above 700 g/kg DM. Season of harvest did not create variation ($P > 0.05$) in NDF content of crop residues. Hemicellulose content in faba bean, field pea and linseed straws were lower ($P < 0.05$) than that of cereal straws digestibility. *In vitro* DM digestibility of barley straw was higher ($P < 0.05$) than that of barley stubble in Dinsho sub district. The IVDMD of crop residues in Sinana sub district was not significantly different ($P > 0.05$), however, the value was higher for faba bean straw and lowest for maize stover. The IVDMD of stubbles of crop residues was lower as compared to the straws, though statistically not significant ($P > 0.05$). There was no seasonal variation in the chemical composition and IVDMD of the crop residues.

DISCUSSION

Available crop residues

Crop residues are the major feed resources, particularly during the dry season in Sinana sub district as compared to Dinsho sub district. The reason for such difference in available crop residues could be attributed to the differences in the manner of land use between the two sub districts, whereby yield of crop residues is related to the area of land allocated for crop production which is higher in Sinana sub district, whereas livestock production is the major means of livelihood in Dinsho sub district (Solomon, 2004). Therefore, more crop residue was available for livestock feeding in Sinana sub district.

Table 4. Chemical composition and *in vitro* dry matter digestibility of barley residues commonly offered to livestock in Dinsho sub district of Bale highlands.

Parameters	Feed description	
	Straw	Stubble
DM (g kg^{-1})	952	950
Ash (g kg^{-1} DM)	56	5.7
CP (g kg^{-1} DM)	40	2.7
NDF (g kg^{-1} DM)	807	819
ADF (g kg^{-1} DM)	562	591
ADL (g kg^{-1} DM)	125	144
Cellulose (g kg^{-1} DM)	399	430
Hemicellulose (g kg^{-1} DM)	245	228
IVDMD (g kg^{-1} DM)	440	320

DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; IVDMD = *in vitro* dry matter digestibility.

Higher yield of wheat straw in Sinana could be associated with the allocation of more land to wheat cultivation, primarily due to availability of seeds of improved wheat varieties and conducive climate leading to high yield, whereas straws from pulses and linseed contributed very low to the animal feed resource base due to the low contribution of the crops to the staple food of the farmers. In Dinsho sub district, barley straw was almost the sole crop residue available for utilization as animal feed due to high altitude predisposing other crops to damage by frost to which barley is relatively tolerant (Bekele *et al.*, 1998). The overall annual available crop residue per household (9 tonnes) in Sinana area is comparable to the 9.35 tonnes straw per household in the highlands of Arsi (Abdinasir, 2000) in Ethiopia. In contrast, Gashaw (1992) found the supply of crop residues to be

1.2 to 2.3 tonnes per household in the central highlands of Ethiopia, where straw contributed only 27% of the annual feed supply. The lower contribution of stubble grazing to the feed resource base in Dinsho as compared to Sinana sub district reflects the differences in the importance of allocation of land for crop cultivation between the two sub districts.

Feeding systems

Draught animals were given priority for feeding on crop residues in the district. The reason for such type of management is to maintain body condition of draught animals, particularly during peak times of cultivation and when the oxen are employed more for cultivation and get less access to grazing on natural pasture. The practice of feeding livestock with straws in the mornings and evenings around homesteads has increased recently due to the reduction of the herbage obtained from natural pasture because of overgrazing of communal grazing areas. Supplementing of livestock fed on crop residues with by-products of oilseeds and other available supplements reflects the awareness of farmers in that crop residues alone do not support adequate livestock performance.

Out of the existing crop residues, barley straw was highly preferred due to its palatability and softness of the stem as compared to either straws of pulses or other cereals. Wheat and emmer wheat residues were equally preferred next to barley straw. Cereal straws were collected and stacked under shade immediately after threshing, however, farmers usually fed pulse straws directly on the field due to the small quantity of pulses production. In Dinsho sub district, farmers were less dependent on crop residues because of less emphasis given to crop production, which limited quantity of available crop residues in the sub district. Livestock were allowed to graze crop stubbles, preferably that of barley twice in a year in Sinana and once in a year in Dinsho sub district, where it is initially reserved and grazed by own stock for a period of one month, and thereafter made accessible to the livestock owned by community members in the locality. This practice allows the better portion of crop stubbles to be utilized through grazing by own stock since land available for stubble grazing is primarily a private holding.

Chemical composition of crop residues

Lower CP content of crop residues in Dinsho sub district may be related to the longer period of time required for physiological maturity of the crop that induces dilution of CP and enhances lignification (McDonald et al., 1995). The CP content of barley straw in this study was similar to the value of 44 g/kg DM reported by Seyoum and Zinash (1989). However, CP content of wheat straw in this study was higher than 24 g/kg DM (Seyoum and Zinash, 1989) and 27 g/kg DM (Gashaw, 1992) reported for wheat straw in the central highlands of Ethiopia. This may be due to differences in variety, management practices and soil fertility in the two areas, which might have altered the leaf to stem ratio, as this was reported to be a major factor in causing nutritional differences among crop residues (McDowell, 1988).

Table 5. Chemical composition (g/kg DM) and *in vitro* dry matter digestibility (g/kg DM) of straw and crop stubbles in Sinana sub district of Bale highlands.

Variables	DM (gkg^{-1})	Ash	CP	NDF	ADF	ADL	Cellulose	Hemicellulose	IVDMD
Crop residues	NS	*	NS	*	NS	NS	NS	***	NS
Wheat straw	942[a]	82[ab]	41[a]	786[a]	476[a]	102[a]	344[a]	310[a]	539[a]
Barley straw	940[a]	98[ab]	45[a]	751[ab]	495[a]	98[a]	334[a]	256[a]	575[a]
Emmer wheat straw	935[a]	90[ab]	41[a]	767[a]	499[a]	90[a]	534[a]	268[a]	578[a]
Field pea straw	944[a]	68[ab]	60[a]	730[ab]	573[a]	164[a]	403[a]	157[b]	544[a]
Faba bean straw	944[a]	103[a]	88[a]	592[b]	468[a]	132[a]	323[a]	124[c]	588[a]
Linseed straw	945[a]	59[bc]	46[a]	753[ab]	609[a]	163[a]	433[a]	144[bc]	526[a]
Wheat stubble	943[a]	82[ab]	35[a]	805[a]	555[a]	120[a]	376[a]	250[a]	436[a]
Barley stubble	947[a]	76[ab]	38[a]	790[a]	544[a]	114[a]	391[a]	246[a]	442[a]
Emmer wheat stubble	945[a]	99[ab]	31[a]	796[a]	562[a]	102[a]	391[a]	234[a]	491[a]
Season	NS	*	NS	NS	NS	NS	NS	NS	NS
Short rainy season	943[a]	91[a]	51[a]	793[a]	519[a]	118[a]	366[a]	224[a]	517[a]
Main rainy season	942[a]	77[b]	41[a]	761[a]	541[a]	123[a]	378[a]	221[a]	531[a]

[abc] means with different superscripts (a, b, c) within a column are different ($P < 0.05$); NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; IVDMD = *in vitro* DM

All straws from the different crops, except that of faba bean, had CP content of less than the critical level of 70 g/kg DM required for optimum rumen microbial function (Van Soest, 1982). This shows that supplementation with a protein source is required for reasonable livestock production in the study area. Under the existing condition, this deficiency may be covered from grazing during the rainy season, since native pasture in the study area contained adequate level of CP during the growing period (Solomon, 2004). However, CP deficiency becomes apparent under conditions when animals lack access to grazing during the rainy season due to pasture enclosure. Quantitatively, lower CP content of crop stubbles than that of straw is due to the low leaf to stem ratio of the crop stubbles, which is in agreement with the reports of Ramazin *et al*. (1986) and Ørskov (1988), who found significant contribution of leaves to CP content of crop residues.

Higher NDF content of crop residues in Dinsho area is probably due to longer time required for crop maturity in the area that provided the chance for fibre accumulation in plant tissues. Generally, NDF contents of crop residues appeared to be close to the previous reports for the central highlands of Ethiopia (Seyoum and Zinash, 1989). Residues of cereal crops had higher NDF content than faba bean straw, which is in agreement with the reports of Daniel (1988) and Brananng and Persson (1990). Roughage feeds with NDF content of less than 450 g/kg DM were grouped as high quality, while those with 450- 650 g/kg DM were categorized as of medium quality, and those with more than 650 g/kg DM were categorized as low quality roughages by Singh and Oosting (1992). Based on their NDF content, all crop residues reported in this study, except that of faba bean may be classified as low quality roughages that may impose limitations on animal performance.

The ADF value obtained for crop residues in this study was comparable, whereas the ADL content for wheat and barley straws and maize stover was higher than that reported by Yitaye *et al*. (2001), which is probably attributable to differences in variety, climate and crop management for the crop residues evaluated in the two studies. Thus, ADL contents of the crop residues in this study were high enough to limit DM intake. The higher cellulose content in stubble crops could have a practical significance on livestock performance in relation to the lignin component, since the increase in lignin level reduces the digestibility of cellulose as well as hemicellulose (Van Soest, 1988) due to physical encrustation of the plant fibre, and making it inaccessible to microbial enzymes (McDonald *et al*., 1995).

In vitro dry matter digestibility

The IVDMD observed in this study for the different crop residues was within the range reported by Daniel (1988) and Gashaw (1992). *In vitro* DM digestibility was higher for barley straw as compared to the stubble in Dinsho sub district, which is related to the higher leaf to stem ratio of the straw that contributed to its higher digestibility. Lower IVDMD for barley straw in Dinsho sub district as compared to that of Sinana sub district is attributable to the higher cell wall fibers and lignin contents in the former. Non- significant effect of season of harvest on IVDMD of crop residues in Sinana sub district was due to the comparable quantity of rainfall as well as temperature range between the two seasons. Crop residues with organic matter (OM) digestibility coefficient of less than 0.5 reduce feed intake to 50 g/kg $W^{0.75}$ or less (Mosi and Butterworth, 1985). Thus, strategic supplementation with protein sources is important to maintain optimum feed intake in animals grazing on crop stubbles in the study area, since the crop stubbles in the study area had less than 0.5 OM digestibility coefficient.

CONCLUSION

Crop residues are one of the major feed resources for livestock, particularly in Sinana sub district. Crude protein content of crop residues was below the critical CP level required for effective rumen microbial function. Similarly, crop residues were low in IVDMD, whereas their fiber content was high enough to limit feed intake. Thus, the crop residues require some degree of supplementation or treatment to support optimum animal performance.

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Livestock production under smallholder mixed cropâ€“livestock (MCL) production systems is constrained by feed shortage and scarcity of land on which to grow feed. Livestock feeds are obtained from different sources including crop residues (CR), grazing lands (GL), crop aftermath, fallow land and purchased.Â Livestock feeds are obtained from different sources including crop residues (CR), grazing lands (GL), crop aftermath, fallow land and purchased. But the contribution of these feed resources and the extent of feed balance at farm level are not quantitatively examined.Â [10] suggested the possible use of livestock feed balance as potential indicator to assess sustainability of the farms.