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Dynamics in nutritional qualities of tef and wheat straws as affected by storage method and storage duration in the central highlands of Ethiopia

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This study assessed the effects of storage method and storage duration on the dynamics in nutritional qualities of tef (Eragrostis tef-cereal indigenous to Ethiopia) and wheat straws in Ejere woreda, central highlands of Ethiopia. The trial was designed with a factorial combination of two storage methods (shelter shade, open-air) and four storage durations (zero, two, four and six months). A total of 12 farmers (six conserving tef straw and the rest six conserving wheat straw) were selected for sampling and evaluation of the crop residues. Among the six farmers conserving each of the crop residues, three of them stored the straws in open-air while the other three used shelter shade. All the measured parameters (DM, ash, CP, IVOMD, ME, NDF, ADF and lignin contents) were significantly ($p<0.05$) affected by storage method and storage durations. The CP, IVOMD and ME contents showed consistently decreasing trends with prolonged storage durations, with higher nutrient losses in straws stored in open air than those stored under shelter. The estimated losses in CP contents during the six months storage period, respectively when stored under shelter and in open air were 30.2 and 41% in tef straw; and 22.3 and 46.9% in wheat straw. Similarly, IVOMD was reduced by 35.8 and 41.1% in tef straw and by 33.3 and 42.6% in wheat straw when stored under shelter and in open air, respectively during the six months storage period. On the other hand, the fiber fractions showed increasing trends with prolonged storage durations, with higher rates of increase in straws stored in open air than those stored under shelter. During the six months storage period, NDF content was increased by 8.5 and 13.6% in tef straw and by 8.9 and 12.9% in wheat straw, respectively when stored under shelter and in open air. The ADF content was increased by 8.4 and 12.2% in tef straw and by 14.9 and 19.3% in wheat straw when stored under shelter and in open air condition, respectively. Lignin content was also increased by 14.2 and 53.1% in tef straw and by 37.7 and 32.2% in wheat straw when stored under shelter and in open air, respectively. The decrease in CP and IVOMD, and the increase in fiber fractions with prolonged storage durations in the crop residues could be attributed to the loss of readily soluble nutrients and the higher concentration of the fibrous materials in the feed DM mainly when stored in open air. The result revealed that quality of crop residues which is inherently low would be substantially reduced further during storage especially when stored in open air. Therefore, supplementation schemes should consider the storage method, storage duration and the associated dynamics in nutritional quality in crop residue-based feeding system of dairy cattle.

Key words: Crop residues, nutritional quality, storage method, storage duration, tef and wheat straws.

INTRODUCTION

Poor animal nutrition and productivity arising from inadequate supply and low quality feed are among the major constraints facing livestock production in developing countries. The fibrous agricultural residues represent a considerable feed resource in the smallholder mixed farming system of the tropics where most of the land is primarily devoted to human food production (Nordbloom, 1988). Crop residues constitute an important source of ruminant feed during the long dry season in mixed crop-livestock farming systems of Ethiopia. According to Zinash and Seyoum (1991), about 70% of crop residues are used as animal feed while other uses and field losses associated with harvesting, collection, transportation and storage account for the remaining 30% in the highlands of Ethiopia. Ethiopian smallholder farmers grow diversified crops and usually produce a mixture of crop residues including the cereal straws like tef, wheat, barley, oats, maize, and sorghum; and different grain legume haulms. There is no exact figure on the quantity of crop residues produced in the country. But, from a total of 12 million ha of land covered by different crops (CSA, 2012), an estimated 40 million tones of crop residues could be produced considering an average grain yield of 1.7 tone/ha and average straw to grain ratio of 2:1 suggested by Daniel (1988). Nevertheless, the actual figure could be likely to be more as various high yielding crop varieties have been cultivated by large number of farmers. As more and more land is put under crop cultivation, grazing lands as sources of feed become scarce and crop residues particularly cereal straws remain the important sources of basal feed for dairy cattle. According to De Leeuw (1997), the potential availability of crop residues for livestock feed increases with an increase in the area of land put under crop production. In areas where the proportion of cropped land is relatively low, the contribution of crop residues to the total feed will be minimal. For instance, Varvikko (1991) reported that in Selale district of Northern Shoa, Ethiopia, where only 40% of the land is cultivated, 40% of livestock feed consisted of stored hay, while only 12% was contributed by crop residues. On the other hand, Gryseels (1988) reported that in the highlands of Ethiopia where grazing lands are being converted to crop land, crop residues and post-harvest stubble grazing accounted for about 90% of all feeds.

Crop residues are generally characterized by high content of fiber (usually above 40%), low nitrogen (0.3 to 1.0%) and low content of essential minerals such Na, P and Ca (Adegbola, 1998; Smith, 1993). Cell wall estimated by neutral detergent fiber (NDF) accounts for at least 72% of the dry matter and represents a large source of potential energy for ruminants (Umunna and Iji, 1993). The ability of rumen microorganisms to digest cell polysaccharides, consisting mainly of cellulose and hemicellulose is limited by lignin. As fiber is often used as a negative index of nutritive value in predicting the total digestible nutrient (TDN) and net energy (Van Soest, 1988), the available energy from crop residues is likely to be low in relation to crop residue yield. The consequences in ruminant animals are low feed intake (about 1.2 kg DM/100 kg live weight) and low performance (Adegbola, 1998). According to Chenost and Sansoucy (1989), feeding value of crop residues is limited by their low voluntary intake, low digestibility and low nitrogen, mineral and vitamin contents. Generally, the quality of a straw or its feeding value is influenced by its chemical composition, level of voluntary intake, digestibility and efficiency of metabolism at the tissue or cell level (Doyle et al., 1986).

The nutritional quality of crop residues which is inherently low is subjected to variations depending up on a number of factors *viz*., species and variety of the crops, stage of harvest, leaf:stem ration, soil fertility, fertilizer application, plant diseases, handling and storage conditions (Preston and Leng, 1986). Particularly crop residue management practices (harvesting, handling, collection and storage) have effects on both the quantity and quality of the residues. Owen and Aboud (1988) stated that harvesting, handling and storage systems should minimize the loss of leaf and leaf sheath (the more nutritious parts) of straws. They further emphasized that delayed harvesting of the crop would be expected to cause greater loss of leaf and leaf sheath, with a consequent reduction in nutritive values. In Ethiopia, since crop residues are produced only once in a year after crop harvest following the main rainy season, their quality and contribution for the annual feed supply depends on proper collection, conservation and utilization. Different studies (Tesfaye and Chairatanayuth, 2007; Funte et al., 2010; Zewdie, 2010) have shown that collection and storage of crop residues is one of the important copping strategies to mitigate dry season feed shortage in different parts of the country. According to Fekede (2013), crop residues are used as sources of roughage feed by dairy cattle on average for about six depending on their level of awareness, resource capacity and intended time of using the stored feed. Despite the anticipation that qualities of crop residues could undergo further reduction during storage, there is no documented information on the dynamics in nutritional qualities of crop

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Table 1. Crop residues (tef and wheat straws) sampling dates for laboratory evaluations.

S/N	Sampling date	Description
1	26 January 2012	At threshing (just prior to storage)
2	26 March 2012	2 months after storage under shade and in open air
3	26 May 2012	4 months after storage under shade and in open air
4	26 July 2012	6 months after storage under shade and in open air

months per year as stored feeds in selected milk shed areas of the central highlands. Some farmers store crop residues in open air while others use shelter shades residues in the process of production, conservation and utilization under Ethiopian condition. Such information will help to design appropriate conservation and management strategies, and also to provide evidence to extensionists, advisors and farmers about proper management and utilization of crop residues, including the supplementation scheme in crop residue based livestock feeding systems.

This study was therefore conducted to assess the effects of storage methods and storage durations on the dynamics in nutritional qualities of tef and wheat straws in the central highlands of Ethiopia.

MATERIALS AND METHODS

Study area and sampling procedures

The study was conducted in Ejere woreda, located about 40km west of Addis Ababa in West Shewa Zone of the Oromia Regional State. The woreda is one of the milk shed areas and well linked to fluid milk market. Moreover, various crops are grown in the area from which different crop residues are produced and conserved for use as feed during periods of feed shortage. The area is closer to Holetta Agricultural Research Center and easily accessible for monitoring and sampling of crop residues for laboratory analysis. The effect of storage method and storage duration on nutritional qualities of crop residues was studied using tef (*Eragrostis tef*) and wheat (*Triticum aestivum*) straws which were the dominantly produced crop residues in the study area. A total of 12 accessible farmers (6 conserving tef straw and 6 conserving wheat straw) were selected based on their willingness to cooperate for monitoring and sampling of crop residues for laboratory analysis. Among the six farmers conserving each of the aforementioned crop residues, three of them stored the crop residues in open air, while the other three used shelter shade for storing the crop residues. Sampling of the crop residues for laboratory analysis began during the time of threshing and continued at two months interval for the subsequent 6 months storage period (Table 1). During each stage of sampling, three samples were collected for each crop residue under the two storage methods. The samples were properly composited, divided into two equal halves and subjected to laboratory analysis in two replications.

Laboratory analysis

After oven drying (65°C, 72h), all the samples collected during the different sampling stages were chopped into shorter fiber lengths and milled through 1-mm sieve size for chemical analysis. The samples were analyzed for dry matter (DM) (oven-dried at 105°C overnight) and total ash using method 924.05 of AOAC (1990). The Kjeldahl wet digestion procedure (AOAC, 1999; method 954.01) was used to determine the total N content. The crude protein (CP) content was then estimated by multiplying the Kjeldahl N by 6.25. The *in-vitro* organic matter digestibility (IVOMD) was determined according to the two-stage rumen fluid technique described by Tilley and Terry (1963). Rumen fluid was obtained from three rumen-cannulated Zebu x Holstein crossbred steers fed on a basal diet of native grass hay and supplemented with 2 kg concentrate per day. The same natural pasture used in this study was the source of the hay fed to the donor animals. Metabolizable energy (ME) content was estimated from IVOMD according to MAFF (1984): ME (MJ/kg DM) = 0.015*IVOMD (g/kg DM). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were determined following the standard procedures (NDF: Mertens (2002), analyzed with heat stable amylase and expressed without residual ash; ADF: AOAC, 1995, no. 973.18, expressed without residual ash after incineration at 500°C for 1 h; lignin: Robertson and Van Soest (1981), determined by solubilization of cellulose with sulphuric acid).

Data analysis

Data was analyzed using Statistical Analysis System (SAS, 2002) and the significance of mean differences was tested using the least significance difference (LSD) method. Differences were considered significant when P<0.05.

The following statistical model was used for analysis for each of tef and wheat straws:

$$Y_{ijkl} = \mu + r_i + s_j + d_k + (s*d)_{jk} + e_{ijkl},$$

where, Y = the measured parameter, μ = the overall mean, ri = effect of i^{th} replication, s_j = effect of j^{th} storage method, d_k = effect of k^{th} storage duration, $(s*d)_{jk}$ = the interaction effects of storage method and storage duration and e_{ijkl} = the random error.

RESULTS AND DISCUSSION

The interaction of storage method and storage duration had no significant effect (p>0.05) on all measured nutritional parameters in both crop residues. The dynamics in DM, ash, CP, IVOMD and ME contents of tef and wheat straws stored under shelter shade and in open air for different durations after threshing are presented in Tables 2 and 3, respectively. Both storage method and storage duration had significant effects (p<0.05) on DM,

Table 2. Dry matter, total Ash, CP, IVOMD and ME contents of tef straw stored under shelter and in open air conditions for different durations.

Storage method	Parameter	Storage duration (months)				Mean±SE
		Zero (at threshing)	Two	Four	Six	
Shelter shade	DM	924.0^{b*}	918.1^{c}	928.1^{a}	894.7^{d*}	916.2±7.5
	Ash	63.2^{c*}	64.9^{a*}	63.7^{b*}	57.8^{d*}	62.4±1.6
	CP	47.1^{a*}	43.9^{b*}	37.6^{c*}	32.9^{d*}	40.4±3.2
	IVOMD	522.3^{a*}	492.3^{b*}	429.4^{c*}	335.6^{d*}	444.9±41.3
	ME	7.9^{a}	7.4^{b}	6.5^{c*}	5.1^{d*}	6.7±0.6
Open air	DM	929.5^{a*}	917.8^{b}	927.9^{a}	855.8^{c*}	907.8±17.5
	Ash	62.8^{b*}	66.1^{a*}	60.2^{c*}	49.9^{d*}	59.8±3.5
	CP	50.3^{a*}	37.9^{b*}	33.2^{c*}	29.7^{d*}	37.8±4.5
	IVOMD	514.8^{a*}	476.6^{b*}	385.4^{c*}	303.3^{d*}	420.0±47.4
	ME	7.7^{a}	7.1^{b}	5.8^{c*}	4.6^{d*}	6.3±0.7

$^{a-d}$Parameter values with different superscripts within a storage method in a row differ significantly ($p<0.05$); *values for the same parameter differ significantly between the two storage methods within a column ($p<0.05$); DM (g/kg); ash, CP and IVOMD measured in g/kg DM; ME (MJ/kg DM).

Table 3. Dry matter, total Ash, CP, IVOMD and ME contents of wheat straw stored under shelter shade and in open air conditions for different durations.

Storage method	Parameter	Storage duration (months)				Mean±SE
		Zero (at threshing)	Two	Four	Six	
Shelter shade	DM	929.8^{b*}	924.0^{b*}	937.0^{a*}	855.0^{c*}	911.5±19.0
	Ash	99.3^{c*}	105.9^{a}	104.1^{b*}	91.6^{d*}	100.2±3.2*
	CP	40.9^{a*}	36.5^{b*}	32.7^{c*}	31.8^{d*}	35.5±2.1
	IVOMD	470.6^{a*}	451.0^{b*}	411.4^{c*}	313.7^{d*}	411.7±34.9
	ME	7.1^{a}	6.8^{b}	6.2^{c*}	4.7^{d*}	6.2±0.5
Open air	DM	934.8^{a*}	919.4^{b*}	935.9^{a*}	863.8^{c*}	913.5±17.0
	Ash	92.0^{b*}	105.7^{a}	85.8^{c*}	78.8^{d*}	90.6±5.7*
	CP	41.6^{a*}	32.2^{b*}	26.3^{c*}	22.1^{d*}	30.6±4.2
	IVOMD	466.3^{a*}	419.8^{b*}	355.4^{c*}	267.9^{d*}	377.4±43.0
	ME	7.0^{a}	6.3^{b}	5.3^{c*}	4.1^{d*}	5.7±0.6

$^{a-d}$ Parameter values with different superscripts within a storage method in a row differ significantly ($p<0.05$); *values for the same parameter differ significantly between the two storage methods within a column ($p<0.05$); DM (g/kg), ash, CP and IVOMD measured in g/kg DM; ME (MJ/kg DM).

ash, CP, IVOMD and ME contents of both the crop residues. The DM content of both the straws showed inconsistent trends along the different durations of storage, but lower values were recorded six months after storage than the earlier storage durations in both storage methods. The DM content of both the straws tended to be higher during forth month after storage (sample taken during the month of May) under both storage methods. This may be attributed to the high loss of moisture from the stored crop residues as a result of higher temperature associated with the long dry season. Similarly, the ash content did not show consistent trends with storage durations, but lower values were recorded six months after storage in both crop residues under both the two storage methods. Wheat straw generally had higher ash content than tef straw which agrees with the reports of various authors under the Ethiopian condition (Kabaija and Little, 1988; Yitaye, 2008; Zewdie, 2010; Firew and Getnet, 2010). In storage, the physical and chemical properties of straws generally deteriorate due to loss of nutrient and water in respiration process. Temperature is one factor that affects respiration rate and preservation of postharvest life in storage. Subsequent to grain harvest, the conditions under which the straw is stored may affect its quality. The degree of protection from the environment appears to determine the extent of storage associated losses in quality. Following the initial and rapid losses of loosely-bound nutrients, rate of loss decreases for nutrients held more tightly in the internal and external structures of the residues (Schreiber and McDowell, 1985).

The CP, IVOMD and ME contents of the two crop residues showed consistently decreasing trend with prolonged storage durations under both storage methods (Tables 2 and 3). However, comparatively higher nutrient losses were recorded in open air storage than under shelter shade storage method. The estimated losses in CP content of tef straw during the six months storage period were 30.2 and 41%, respectively when stored under shelter shade and in open air. Likewise, CP content of wheat straw was reduced by 22.3 and 46.9% when stored under shelter shade and in open air, respectively during the six months storage period. The higher loss in CP content recorded for wheat straw than tef straw under the open air storage method may be attributed to the fact that tef has a fine stemmed straw which can be firmly stacked in such a way to minimize percolations of rain water and exposures to other inclement weather conditions. Devendra (1982) reported a preliminary investigation of the effects of storage conditions on the chemical composition of the straws. The three conditions investigated in his study represent fully exposed straw, partially exposed straw and straw kept under shelter. Exposure to the weather decreases crude protein content from 5.6 to 3.4%, Ca from 0.31 to 0.21% and P from 0.11 to 0.02%. To optimize the feeding value of cereal straws it is preferable to store them under cover and keep them in a dry condition. Since residues have no ability to acquire replacement of nutrients once separated, detached organs lose a larger percentage of their initial concentrations when exposed to leaching (Marschner and Marschner, 2012). The extent of protection of straw during storage varies widely. Under good storage conditions the general experience is that little deterioration in nutritive value occurs. However, deleterious effects have been recorded when effective protection has not been provided. The major causes of nutrient loss during storage as described by Tripathi et al. (1995) include shattering loss of leaves, leaching of soluble nutrients by rain, potentially large losses due to mold damage and bleaching by exposure to sunshine.

The reductions in IVOMD of tef straw during the six months storage period are estimated to be 35.8 and 41.1% under shelter shade and in open air storage methods, respectively. Similarly in wheat straw, IVOMD was reduced by 33.3 and 42.6%, respectively when stored under shelter shade and in open air during the six months storage period. The ME content is also reduced by 35.4 and 40.3% in tef straw and by 33.8 and 41.4% in wheat straw, respectively under shelter shade and in open air storage methods during the six months of storage duration. The result clearly depicted that storage in open air resulted in higher nutrient losses in tef and wheat straws. This calls for the need to examine our feeding strategies (especially supplementation schemes) accordingly when feeding dairy cows using crop residues as basal diets. The research result indicated that heavy rain may leach out the cell contents resulting in low digestibility (Pearce et al., 1979). Similar effects would be expected under conditions of inadequate protection from moisture when cut straw is stored. In addition, moldiness may reduce the acceptability of the material to animals.

Pearce et al. (1979) reported that rain damaged cereal straw has lower quality than undamaged straw. The *in-vitro* organic matter digestibility of the straws which have suffered by rain damage ranged from 25 to 34% compared with 30 to 49% for the undamaged straw. It is likely that leaching of water soluble carbohydrates was the major effect of the rain damage but under prolonged shower conditions, microbial and fungal actions may also depress the concentration of fermentable constituents. Rainfall intensity plays a major role in crop residue nutrient loss. As with standing plants, residues leach larger volumes of nutrients in conditions of prolonged low rainfall intensities than in short periods of heavy rainfall as a result of the slower saturation rate, time to runoff and prolonged straw-water contact (Schreiber and McDowell, 1985). Variation in rate of nutrient loss depends on individual nutrient leachability (Schreiber and McDowell, 1985). Nutrient leaching in both corn and wheat residues follow a hyperbolic pattern and nutrient loss in wheat straw is very rapid. One study demonstrated that the most nutrient loss from wetted straw occurred in the first few minutes of a 60 min rainfall period (Schreiber, 1985). Corn stover follows a similar leaching pattern (Schreiber, 1985; Schreiber, 1999); after 212 days of exposure to simulated rainfall events, losses of P, N (NO3-N plus NH4-N) and C were measured to be 0.92, 2.04 and 43 kg ha^{-1}, or 6, 1.3 and 1% of total corn residue nutrient content, respectively. However, 76, 62, and 77% of P, N and C, respectively were lost in the first 90 days of the experiment (Schreiber, 1999). All these evidences indicate that postharvest handling and storage of straws can have significant effects on final straw quality.

Tables 4 and 5 indicate the dynamics in contents of the fiber fractions (NDF, ADF and lignin) in tef and wheat straws, respectively as affected by storage method and

Table 4. NDF, ADF and lignin contents of tef straw stored under shelter shade and in open air conditions for different durations.

Storage method	Parameter (g/kg DM)	Storage duration (months)				Mean±SE
		Zero (at threshing)	Two	Four	Six	
Shelter shade	NDF	720.6^{d}*	739.4^{c}*	765.3^{b}*	781.8^{a}*	751.8±13.6
	ADF	458.9^{d}*	466.6^{c}*	483.1^{b}*	497.3^{a}*	476.5±8.6
	Lignin	75.3^{c}*	72.9^{d}*	79.8^{b}*	86.0^{a}*	78.5±2.9*
Open air	NDF	723.5^{d}*	764.3^{c}*	795.4^{b}*	822.2^{a}*	776.4±21.2
	ADF	464.6^{d}*	493.0^{c}*	502.6^{b}*	521.1^{a}*	495.3±11.8
	Lignin	81.0^{d}*	96.3^{c}*	98.9^{b}*	124.0^{a}*	100.1±8.9*

$^{a-d}$Parameter values with different superscripts within a storage method in a row differ significantly ($p<0.05$); *values for the same parameter differ significantly between the two storage methods within a column ($p<0.05$).

Table 5. NDF, ADF and lignin contents of wheat straw stored under shelter shade and in open air conditions for different durations.

Storage method	Parameter (g/kg DM)	Storage duration (months)				Mean±SE
		Zero (at threshing)	Two	Four	Six	
Shelter shade	NDF	730.8^{d}*	754.9^{c}*	776.1^{b}*	795.9^{a}*	764.4±14.0
	ADF	502.9^{d}*	513.4^{c}*	545.7^{b}*	578.0^{a}*	535.0±17.0
	Lignin	70.8^{d}*	78.4^{c}*	88.0^{b}*	97.5^{a}*	83.7±5.8
Open air	NDF	734.9^{d}*	772.1^{c}*	797.3^{b}*	829.5^{a}*	783.5±20.0
	ADF	505.4^{d}*	532.9^{c}*	579.2^{b}*	603.2^{a}*	555.2± 22.1
	Lignin	77.4^{d}*	91.5^{c}*	97.6^{b}*	102.3^{a}*	92.2±5.4

$^{a-d}$Parameter values with different superscripts within a storage method in a row differ significantly ($p<0.05$); *values for the same parameter differ significantly between the two storage methods within a column ($p<0.05$).

storage duration. Both storage method and storage duration had significant effects ($p<0.05$) on the fiber contents of both the crop residues. In contrary to CP, IVOMD and ME contents shown in Tables 2 and 3, the fiber fractions showed increasing trends with prolonged storage durations under the two storage methods in both the crop residues except for the lower lignin content recorded two months after storage than the figure recorded at threshing in the case of tef straw. The increase in NDF content of tef straw during the six months storage period are estimated to be 8.5 and 13.6%, respectively when stored under shade and in open air conditions. Similarly, NDF content of wheat straw is increased by 8.9 and 12.9% when stored under shelter shade and in open air conditions, respectively during the six month storage period. The estimated increases in ADF content of tef straw during the six months storage period are 8.4 and 12.2% when stored under shelter shade and in open air conditions, respectively.

In wheat straw, ADF content was increased by 14.9 and 19.3%, respectively when stored under shelter shade and in open air conditions during the six months storage period. The lignin content was also increased by 14.2 and 53.1% in tef straw and by 32.2 and 37.7% in wheat straw, respectively when stored under shade and in open air conditions during the six months storage period. It was generally noted that storage under open air condition resulted in higher concentrations of the fiber fractions in crop residues (tef and wheat straws in this case). The increasing trend in contents of the fiber fractions in the straws with prolonged storage durations could be attributed to the loss of readily soluble nutrients and the consequent higher concentration of the fibrous materials in the feed DM mainly when stored in open air condition. Concentrations of the fiber fractions were comparatively higher in wheat straw than in tef straw. This was in agreement with the reports of different authors in the country (Kabaija and Little, 1988; Yitaye, 2008; Zewdie, 2010; Firew and Getnet, 2010). The higher contents of the fiber fractions in wheat straw than in tef straw may be attributed to the relatively thick stem with higher concentrations of cell wall materials in the former crop residue than the latter.

Conclusion

Both storage method and storage duration had considerable effects on nutritional qualities of tef and wheat straws. The CP, IVOMD and ME contents of both the crop residues showed consistently decreasing, while the fiber fractions showed consistently increasing trends with prolonged storage durations under both storage methods. However, the dynamics in nutritional qualities (the rates of decline in CP, IVOMD and ME, an increase in the fiber fractions) were higher when the crop residues were stored in open air than under shelter shade. Generally, the nutritional quality of tef and wheat straws which is inherently marginal to livestock/dairy cattle nutrition is liable to further substantial reductions during storage, mainly under open air storage conditions. Therefore, supplementation schemes should consider the storage method, storage duration and the associated dynamics in nutritional quality in feeding systems where tef and wheat straws are used as sources of roughage feed by dairy cattle and other livestock species.

Conflict of Interest

The author(s) have not declared any conflict interest.

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