Evaluation of EM-2 as Biological Crop Residue Treatment Option Targeted for Feeding Crossbred Dairy Cattle

*Getu Kitaw[*1], Aemiro Kehaliw, Getnet Assefa and Fekede Feyissa*
Corresponding author=kitaw2006@yahoo.com
**Holetta Agricultural Research center, Ethiopian Institute of Agricultural Research, Addis Abeba, ethiopia*

Abstract

A study was conducted at Holetta Agricultural Research Center with the objective to evaluate the effect of ensiling crop residues (wheat, barley and oat) with extended EM solution (EM2) on the nutritive value, in-vivo digestibility coefficients and animal response. Accordingly, crude protein (CP), DOMD (digestible organic matter in the dry matter), EME (estimated metabolizable energy), total ash, NDF (Neutral detergent fiber), ADF (Acid detergent fibre) and lignin (P<0.05) were significantly (P<0.05) improved by EM2 treatment as compared to the untreated straws. On the contrary, DM (dry matter) & OM (Organic matter) losses as a result of EM-2 treatment were substantial (P<0.05) for all the three residues under investigation. Barely straw was found to be higher (P<0.05) for all chemical compositions and in-vitro digestibility values except DM & OM. The rate of change calculated as percentage differences over the original untreated residue was higher for the relatively inferior quality wheat straw. From the result of the first laboratory trial, application of EM2 at the rate of 1 liter per kg straw mass have been seen to adequately improve chemical compositions and in-vitro digestibility of cereal residues. In the second trial were mid lactating Boran-Fresian crossbreds cows have been fed with either ad libtum EM2 treated or untreated barley straw and supplemented with different levels of on-station formulated dairy concentrate @ 0.3, 0.5 and 0.7 kg/liter of milk daily intake of EM2 treated barley straw was significantly improved (P<0.05) for all experimental cows other than those on the control diet. Daily total DM intake followed same trend as for the basal feed intake. Among experimental cows receiving treated straw basal diet cows on dietary T3 consumed superiorly higher (P<0.05) daily total feed intake. In general, daily intakes for all nutrients under considerations were higher (P<0.05) for cows fed the EM2 treated barley straw as a basal diet on a daily basis. While maximum daily nutrient intake (P<0.05) was recorded for cows receiving T3 lower intakes (P<0.05) were recorded for cows that have received the control diet. There was no difference (P>0.05) for apparent digestibility of DM & OM. Higher digestibility coefficients of CP, NDF and ADF were recorded for cows maintained under dietary T3. Daily milk yield and compositions except milk lactose and total solids were statistically different (P<0.05) among cows that were fed with the treated barley straw diet and when same cows were compared with those that have been fed with the untreated barley straw basal diet. Higher milk (P<0.05) was, however, produced by the cows receiving dietary T3. However, due to high cost of straw treatment compared to cows on the control diet the gross and net profit obtained from intervention treatments were marginal.

Key words: Effective Microorganism, Activated EM (EM2), barley, wheat and oat straws

Introduction

In most developing countries the feed resources for ruminant production are predominantly based on crop residues especially cereal straws. Thus the upgrading of straw quality is still a central issue as a strategy for improving ruminant livestock production (Preston and Leng, 1987). During the last two to three decades both scientists and extension workers have shown great interest in chemical and physical treatment of straw (Sundstol and Owen 1984). The ammoniation method using urea has received major attention as an appropriate system for developing countries (Owen and Jayasuriya 1989a). However, the success of ammonia treatment as well as other chemical methods in application on the farm level has generally been disappointing. There are several reasons for this, but the economic constraints may be the main one (Devendra 1991; Owen and Jayasuriya 1989b). Zhang Weixian (1994) developed an economic model for the ammonia treated straw feeding system and concluded that if the price ratio between urea-ammonia and concentrates rose above 2.5:1, this system would not be profitable. In the meantime, in many developing countries the urea: concentrate price ratio has already been close to this figure. It is therefore necessary to develop alternative treatment technologies for ruminant livestock production. Many attempts have been made by scientists to find other efficient approaches to this problem. The use of cereal-based concentrates is not a long term solution because with a large and increasing human population and limited grain production, the animal production industry in Ethiopia must direct its attention toward the use of crop residues whose total production is estimated to amount some 24 million tonnes per annum (CSA, 2014). Moreover, presently relative contribution of crop residues to ruminant livestock can be roughly estimated to rich 50% of the total produce. A promising alternative to urea treatment is a microbial fermentation method. This method is simple in application and is of low cost, and the farmer can use the same urea-ammonia treatment facilities to carry out the process. Ensiling of dry crop residues involves actions such as chopping, reconstitution of moisture, pressing and mixing with certain additives, including microorganisms such as lactic acid producing bacteria (LAB), cellulolytic bacteria, for proper fermentation and nutrient preservation. A large number of dry crop residues have been successfully ensiled with addition of microorganisms. It was shown that microbial ensilage of crop residues increased daily gains, feed intake and feed conversion, and decreased feed cost per unit gain in growing ruminants. In this regard, lactating cows fed diets based on microbial ensiled straw had increased milk and fat-corrected milk yield, and slightly higher milk fat percentages compared with diets based on untreated straw (Zhang and Meng 1995; Ma and Zhu 1997). Another significant effect of microbial ensilage of dry crop residues is probably to hydrate and weaken plant structures so that less energy is expended on rumination (Tingshuang *et al.* 2002). The technology of Effective Microorganisms as biological inoculants was developed in the 1970's at the University of the Ryukyus, Okinawa, Japan. The inception of the technology was based on blending a multitude of microbes, and was subsequently refined to include three principal types of organisms commonly found in all ecosystems, namely Lactic Acid Bacteria, Yeast

Actinomyces and Photosynthetic bacteria (Higa, 1996). The use of EM in animal husbandry is clearly identified in many parts of the world (Konoplya and Higa, 2000; Hanekon *et al*., 2001; Safalaoh and Smith, 2001).

However, although the possibility of a biological method of straw treatment has a great appeal as an alternative to the use of expensive (in terms of money and energy) chemicals and environmental pollution (Jackson 1978), so far, despite encouraging laboratory experiments, none of the microbial processes has brought an impact with farmers (Sundstol 1988). Many failures of biological straw treatment have been described in the literature, although some improvement in nutritive value seemed possible. Thus, before any new biological fermentation method is applied extensively, many aspects need further investigation. The objective of this study was hence to evaluate the new microbial inoculants EM2 as a technologically feasible alternative crop residue treatment and feeding options for dairy cattle in Ethiopia.

Methodology

Description of study areas

The study was carried out on-station at Holeta Agricultural Research Center. The center is located at 9^{o} 3' N latitude and 38^{o} 30' E longitudes, about 35 km West of Addis Ababa along the main road to Ambo. The study area has an altitude of 2400 meters above sea level (m.a.s.l) and receives an average annual rainfall of about 1055 mm. The mean minimum and maximum temperatures are 6.1^{o}C and 22.2^{o}C, respectively. The area is a typical mixed crop livestock production system, where small scale dairying based on crossbred animals is found here and there. The soil type in the area is largely Nitsols and major crops grown are *teff*, wheat, barley, oats, potato, field pea, faba bean and linseed.

Experimental Trials

The study consisted of two trials conducted consecutively in two major phases. The first trial was laboratory evaluation through chemical analysis and *in-vitro* OM digestibility of three major cereal crop residues namely wheat, barley and oat straws treated with extended EM solution (EM2) while the second trial has dealt with animal response feeding trial where the EM2 treated basal straw was evaluated against untreated residues using lactating crossbred cows supplemented with graded levels of on-station formulated dairy concentrate

Trial one

This trial has focused on ensiling three cereal crop residues, i.e., wheat, barley and oat straw with EM2 (extended EM solution). EM2 was prepared by mixing EM1, Molasses and Chlorine free water in the ratio of 1:1:18 respectively. 10% molasses was added to the solution to provide nutrients specifically sufficient soluble carbohydrates to the microbes in the EM2 solution, which would facilitate the ensiling process. EM2 solution was then applied to the residues at the rate of 0, 1 and 1.5 liters per kg dry matter of the residues. Except for the untreated crop residue the materials were then incubated for 30 and 40 days using airtight plastic containers using the protocols indicated in Table 1 below.

Table 1.Ensiling protocol of the three crop residues with EM2 solution

Type of crop residues	Type of treatment	Level/rate of application (liter/Kg DM)	Duration of incubation days
Wheat, Barley and Oat straws	EM2	0, 1 and 1.5	30, 40

Straws of wheat, barley and oat samples from known varieties were collected from on-station plots and subjected to chopping to an approximate size of 3-5cm.

At the end of the incubation period part of the silage mass was subjected to oven drying at 65^{o}C for about 72hours for partial DM determinations and further processing to 1mm sieve size grinding for laboratory chemical compositions and in-vitro organic matter digestibility studies.

Trial two

In this trial, the crop residue that has responded to EM2 treatment much better than the others for chemical compositions and *in-vitro* digestibility fractions from trial set-one was supposed to be selected for next *in-vivo* trial on lactating crossbred cows. According to the finding from the laboratory trial wheat straw was the appropriate candidate basal feed for the feeding trial. Unfortunately, because of luck adequate amount of wheat straw decision was made to shift the basal diet for EM2 treatment to barley straw.

Experimental Animal Preparation and Management

A total of four lactating F1 crossbred cows (Boran x Friesian) were used for this experiment. Experimental cows with similar lactation performance (8-10 lt/h/d), same stage of lactation (mid-lactating i.e., three months after calving), body weight of (393$\pm$25kg) but differing in parities (two through five) were selected from the total dairy herd available on station. All the cows were weighed and drenched with broad-spectrum anti-helminthics (Albendazole 500mg) prior to the start of the experiment. The cows were individually stall-fed in a well-ventilated barn with concrete floor and appropriate drainage slope and gutters.

Experimental Design, Treatments and Measurements

At the beginning of the experiment, four cows were randomly blocked in a simple 4X4 Latin Square Design. There were, in general, 4 experimental cows, 4 treatment diets and 4 periods. The length of each period was 28 days out of which 21 days were allocated for adaptation while

the remaining 7 days were used for actual data collections for analysis. In total, the feeding trial has taken about 112 days. All cows were hand- milked twice a day and milk yield was recorded daily. Aliquot samples of morning and evening milk was collected weekly to analyze milk chemical composition. Water was available at all times free of choice. The experimental animals were randomly allotted to one of the four dietary treatments given below.
Experimental treatments were:-

- Treatment 1: EM2 treated barley straw basal diet *adlibitum* + (0.3kg concentrate mix /liter of milk produce
- Treatment 2: EM2 treated barley straw basal diet *ad libitum*+ 0.5kg concentrate mix /liter of milk produce
- Treatment 3: EM2 treated barley straw basal diet *ad libitum*+ (0.7kg concentrate mix /liter of milk produce
- Treatment 4 (control diet): Untreated barley straw *ad libitum* + 0.5 kg concentrate mix /liter of milk produce

The cows were supplemented twice a day with a standard on-station formulated dairy concentrate mixture (76% wheat bran, 23% noug seed cake and 1% salt). The mix was assumed to fully meet the requirement for protein (20%) of lactating crossbred cows with milk yield of 8-10 liter /day and a butter fat content of 4.5% as described in ARC (1990) when fed as supplement at the rate of 0.5 kg/liter of milk.

Feed offer and refusals were measured and recorded for each cow to determine daily feed and nutrient intake. Feed offer and refusal samples were taken daily and weighed per cow, bulked on a period bases and oven dried at 65^{0}C for 72h. Samples were then ground using Cyclo-Tec sample mills to pass 1 mm sieve size for DM analysis to calculate feed intake.

Experimental Feeds and Their Preparation

Wheat straw was supposed to be used as a basal diet since it has responded EM2 treatment much better than barley and oat straw. Unfortunately, there was no adequate wheat straw enough to be treated for use as basal feed to experimental animals over the entire experimental period. The feed used as a basal diet in this study was hence barley straw (variety: HB1307). The concentrate was a mix prepared on-station from wheat bran, noug seed cake and salt as indicated in section 2.4 above. Barley straw collected from Holetta Agricultural Research Center was harvested by combine harvester, immediately baled and stored in hay shed until it was ready to be chopped to a size of 3-5cm using electrical chopper.

The process of ensilage begins with spraying of properly prepared EM2 solution to the barley straw at the rate of 1lt per kg straw mass. The treated barley straw was compacted and then allowed to ferment for one month in an air tight plastic barrel of (250 lt) capacity before it was being fed to the animals.

Diet Apparent Digestibility

Apparent digestibility was determined for the total ration in each treatment using the procedures of total fecal collection method for a period of 5 consecutive days at around the end of each experimental period. To minimize error in faces collections, farm personnel were assigned around the clock to scoop faeces into plastic buckets when the animals were defecating. Urinal contamination was minimized by frequent washing of the concrete floor with high pressure running water using a plastic water hose. Individual cow's faces were weighed every morning before 8:00am and before fresh feeds were given to the animals. The faeces from each cow were thoroughly mixed and a sample of 1% were taken and placed in polyethylene bag. Composite samples of the daily collected samples were mixed and stored in a deep freezer (-20^{o}C) until the end of the collection period. At the end of the collection period, the pooled samples were thawed and mixed thoroughly and samples were oven dried at 65^{o}C for 72 hours, ground to pass a 1mm sieve and stored in sample bottles at room temperature. Composite samples of EM2 treated barley straw, untreated barely straw, concentrate mix and fecal output were analyzed for DM, ash, CP, NDF and ADF. Apparent digestibility of DM and nutrients was determined using the formula:

$$Apparentdigestibility(\%) = \frac{(\text{DM or nutrient intake} - \text{DM or nutrient in feaces})}{\text{DM or nutreint intake}} \text{ X } 100$$

Milk Yield and Composition

The cows were hand- milked twice a day at 5:00am in the morning and 16:00pm in the afternoon and milk yield was recorded individually for each animal. 100ml of milk Aliquot samples from the morning and evening milking were taken every week for laboratory determination of major milk chemical compositions that includes milk fat, protein, lactose and total solids. The sampling bottle was properly cleaned and sanitized before samples were taken to Holetta Agricultural Research Center dairy laboratory.

Chemical Analysis

All samples of feeds from laboratory trial in phase one, feed offer and refusals samples from the feeding trial in phase two and faces samples from digestibility trial were analyzed for DM, ash, N (Kjeldahl-N) according to the procedures of AOAC (1990). Neutral detergent fiber (NDF), Acid Detergent fiber (ADF) and permanganate lignin were determined by the method of Van Soest and Robertson (1985). *In-vitro* organic matter digestibility of feeds offered was determined according to the procedures outlined by Tilley and Terry (1963). Hemi-cellulose was calculated as a difference between NDF and ADF. Metabolizable energy (ME) value was estimated from the *in-vitro* organic matter digestibility (IVOMD).

EME (MJ/kg) =0.16(IVOMD) according to McDonald *et al.* (2002).

Gerber method (AOAC, 1980) was used for milk fat analysis, while the formaldehyde titration method (Pyne, 1932) was used to analyze milk protein. Total solids in the milk were determined using the procedures described by Richardson (1985). Lacto scope milk product analyzer was used for lactose determination.

Statistical Analysis

Analysis of variance was made using a statistical soft ware package SAS (SAS, 2002). Data from the first trial was analyzed using CRD model in 3x3x2 factorial arrangements. All data from the feeding and digestibility trial was analyzed using a simple 4X4 Latin Square Design. Treatment means were separated using Least Squares Significant difference (LSD). The models for both designs are indicated below:

1. Model for CRD in factorial arrangement

   $Y_{ijk} = \mu + C_i + L_j + CL_{ij} + e_{ijk}$

Where;

μ = Overall mean C_i = Effect of type of crop residue L_j =Effect of level of application of EM2
CLij = Interaction effect e_{ijk} =Random error

2. Model for simple 4X4 Latin Square Design

$Y_{ijk} = \mu + C_i + P_j + T_k + E_{ijk}$,

Where: μ = Overall mean C_i = Cow effect (parity) P_j = Period effect T_k = Treatment effect
E_{ijk} = Experimental error

Results and Discussion

Chemical Compositions and *In-vitro* Digestibility of EM-2 treated Major Cereal Residues

Responses of major cereal residues to EM-2 ensiling are presented in table 1 below. According to laboratory chemical analysis, there was significant improvements (P<0.05) in the total ash and CP, NDF, ADF, lignin and DOMD contents of major cereal residues ensiled with EM2. For ash this amounts to 20.8%, 22.8% and 19.2% for oat, barley and wheat straw, respectively over their untreated counterparts. The increment for CP was 14.6% for oat, 14.2% for barley and 25.5% for wheat over the untreated residues. Similarly, percentage DOMD increments over untreated residues were 19.5%, 26.0% and 39.5%, respectively for oat, barley and wheat straw. Cell wall constituent that has shown increment by 13.6%, 27.1% & 44.7% over the untreated residues of oat, barley and wheat, respectively was hemicelluloses. On the other hand, when EM2 was used as biological inoculants there was significant (P<0.05) reductions in the DM, OM and cell wall (NDF, ADF and lignin) constituents of the residues over the untreated residues. The reduction for DM of oat, barley and wheat straw was 1.8%, 0.6% & 1.7%, respectively while it was 2.0%, 1.9% and 1.6% for OM contents of the residues in the same order as for the DM. The percentage improvement in NDF contents of the residues were 4.8%, 5.6% & 6.1% for oat, barley and wheat straw, respectively while EM has improved the remaining cell wall constituents of oat, barley and wheat straw in that order by 9.6%, 13.5% & 20.0% for ADF; and 9.30%, 25.2% & 19.6% for lignin.

Table2. Response of major cereal residues to EM2 ensiling

Treatment	**Average nutritive value expressed as % DM**								
	DM	Ash	OM	CP	NDF	ADF	H-cell	Lignin	DOMD
Oat untreated	93.06^{b}	8.81^{c}	91.19^{b}	1.92^{e}	80.69^{e}	63.94^{d}	16.75^{c}	9.68^{b}	38.89^{d}
Barley untreated	93.47^{a}	7.59^{d}	92.41^{a}	2.74^{b}	79.58^{d}	64.14^{d}	15.44^{d}	10.94^{bc}	38.94^{d}
Wheat untreated	93.78^{a}	7.70^{d}	92.30^{a}	1.65^{f}	82.99^{f}	65.21	^{b} ^{c}	11.88^{c}	29.64^{e}
EM2 treated Oat	91.43^{d}	10.64^{a}	89.36^{d}	2.20^{c}	76.84^{b}	57.81^{c}	19.03^{b}	8.78^{ab}	46.46^{b}
EM2 treated barley	92.88^{b}	9.32^{b}	90.68^{c}	3.13^{a}	75.10^{a}	55.48^{b}	19.62^{b}	8.18^{a}	48.67^{a}
EM2 treated wheat	92.23^{c}	9.18^{bc}	90.82^{bc}	2.07^{d}	77.90^{c}	52.18^{a}	25.72^{a}	9.55^{b}	41.36^{c}
Mean±SE	92.81 ±0.32	8.87 ±0.42	91.13 ±0.42	2.29 ±0.20	78.85 ±1.05	59.79 ±2.01	19.06 ±1.34	9.84 ±0.51	40.66 ±2.50
CV%	1.07	7.08	0.69	1.56	2.17	10.12	14.82	7.26	6.16

`Means with different superscripts along a column are significantly different (P=0.05)

In general, all nutritional constituents in the residues were positively influenced by EM treatment. However, above all, responses of the residues to change in ash, CP, DOMD and cell wall constituents because of EM2 ensiling were quite appreciable. Among the treated residues wheat straw followed by barley straw was considerably much influenced by EM2 treatment supporting previous notions that poor quality residues will always respond much better than residues with relatively better nutritional qualities. The reduction in DM & OM contents of EM2 ensiled crop residue from the current trial is also in agreement with previous report by EL-Tahan (2003) who pointed out that chemical composition of wheat straw, fungally treated with *Agaricus bisporus* decreased slightly the DM content compared with those in the untreated wheat straw. Salman *et al.* (2011) held an experiment that aimed to evaluate the effect of biological treatment with fungi, yeast and bacteria or their combinations on the nutritive value of sugar cane bagassie (SCB). Similar to the present finding they found a decreased DM for treated residues while the ash was observed to have been significantly ($P<0.05$) increased. Under local condition increased ash contents have also been observed by Yonatan *et al.* (2014) for coffee pulp treated and ensiled with EM solution. The decrease in the OM contents of EM treated residue from the current trial can be matched with the reports of El-Marakby (2003) and El-Banna *et al.* (2010b) who treated wheat straw and SCB with different strains of fungus *was able to* notice great decrease in content of OM for treated residues than the untreated once. The increment in ash contents for EM treated residues can be linked to the presence of molasses (reported to have high levels of minerals). Reduction in the DM and OM contents in the present trial according to El-Ashry *et al. (*2003) and Rolz *et al*. (1986) can be liked to microbial solublizing and fermentation of organic materials (mainly structural carbohydrates) as energy sources for their own growth and multiplications.

The average CP improvement over the untreated residues (i.e., 17%) from the current trial can fairly be compared with previous research findings of 19.2% for various microbial treated fibrous basal diets by Nahla *et al.* (2015) and El-Marakby (2003). Improvements made for CP contents of EM2 treated residues may be due to one of the following reasons: the presence of microorganisms, extracellular enzymes and residual media ingredients in the treated materials (Siddhant and Singh 2009; Khattab *et al.* 2013), the capture of access nitrogen by aerobic fermentation by fungus (Akinfemi, 2010), and the proliferation of fungi during degradation (Akinfemi and Ogunwole 2012).

The increments in CP contents due to EM treatment, however, were so much marginal compared to progress made with biological treatments earlier for other fibrous diets. El-Banna *et al.* (2010b) found higher CP (1.6 *vs*. 11.1%) for SCB treated with fungi. Similarly, Gado (2012) reported increased CP (1.9 Vs 11.2%) for SCB treated with a biological agent ZAD® for an ensiling period of four weeks. Additional literatures by Akinfemi and Ogunwole (2012) and Omer *et al*. (2012) reported CP contents (4.69 % Vs 7.69 %; 4.29 Vs 11.43%) all of which are by far larger than the mean CP values (1.9% Vs 2.2% for oat straw), (2.7% Vs 3.1% for barley) and (1.6% Vs 2.1% for wheat straw) recorded for EM treatment of major cereal residues from the current trial. It is a well established fact that biological treatment of poor quality roughages usually result in marked increases in CP contents when treatment conditions were appropriate. But this was not the case from the present finding majorly because of the luck of reconstituting the residues with water prior to EM applications, the difference in microbial type and strains used for biological treatment and luck of freeze drying for processing the silage material for lab analysis.

The observed increment in *in-vitro* organic matter digestibility of the residues ensiled with EM could be attributed to the reduction in percentage composition of major cell wall constituents (NDF, ADF and lignin). The yeasts and bacterial species present in the EM might have induced positive effect reflected by improvement in the corresponding *in-vitro* dry matter digestibility values of the treated residues. Especially the role of yeast in the EM solution is quite indispensable since yeasts have been reported to utilize feeds with high structural components (Maurya, 1993). The maximum improvement in DOMD% brought about by EM2 treatment over untreated residue from the current trial was the one that was recorded for wheat straw (39.5%). The average improvement over the untreated residue (i.e., 28%) was close to the figure (30%) reported earlier for coffee pulp ensiled with EM by Yontan (2014). With the exception for barley straw the *in-vitro* organic matter digestibility recorded for the other treated residues from the present trial was, however, lower than the threshold digestibility (50%) recommended for poor quality roughages by Aramble and Tung (1987). IVOMD figures as high as 57.02% recorded for rice straw treated with different strains of fungi have also been reported earlier by Akinfemi and Ogunwole (2012). Disparities in DOMD values with previous findings can be explained by the type of microbes and/or microbial strains used, quantities applied, straw type and quality and above all preconditions required to be fulfilled for biological treatment.

Application of EM inoculates on in fibrous feed stuffs have been previously reported to have increased the quality of the silage by decreasing fibrous contents of the silage (NDF and ADF) (Higa and Wididana, 2007). A decrease in NDF and ADF content of the silage could be due to the addition of molasses to the silage which in its effect can increase the number of anaerobic bacteria (lactic acid bacteria: *Lactobacillus plantarum; L.casei; Streptococcus Lactis) and* yeast (cercomycae cervicae) capable of degrading the lingo-cellulotic complexes in the cell wall fractions of the silage material through their oxidizing and solublizing effects. Several other authors were also able to note (Fayed *et al.*, 2009 and Mahrous *et al.*, 2009) similar effect by fungus that it can degrade cellulose and hemi-cellulose by oxidizing and solublizing the lignin component. In the current trial the main effect of EM as in any other probiotics for biological treatment of fibrous residues was the reduction in the cell wall constituents of the residues (see table 2 above). The result from this research work is, therefore, in agreement with earlier findings by Salman *et al.* (2011) who conducted an experiment aimed to evaluate the effect of biological treatment with fungi, yeast and bacteria or their combinations on the nutritive value of SCB. They found that the NDF, ADF, cellulose and hemicellulose contents were significantly decreased compared to untreated ones. The current result is also in pare with the findings of El-Marakby (2003) who found a great decrease in content of neutral detergent fiber (NDF- 45.1%), acid detergent fiber (ADF- by 31.5%), cellulose (by 53.7%), hemicellulose (by 96.3%) for wheat straw treated with white rot fungus *Agaricus bisporous*. Similarly, Gado (2012) and El-Banna *et al.* (2010b) had same observation with the current finding about the reduction of cell wall constituents typical of the NDF, ADF and ADL fractions after a SCB was being treated and ensiled with microbial agents such as ZAD® and brown rot fungi (*Trichoderma reesei* F-418). However, the magnitude of reduction in fiber constituents from current trial was relatively lower compared to earlier findings. Same factors mentioned above for CP and *in-vitro* OMD could be responsible for the induced variability between the present and previous findings.

Response of Crop Residues to Levels of EM2 Applications and Durations of Incubations

Responses of major cereal residues to quantities of EM2 applied per kg straw mass and days required to come up with best quality straw silage as measured through chemical compositions and *in-vitro* organic matter digestibility is shown in table 3 below. Except for DM and ash the level of application of EM2 solution per kg straw mass was non-significant (P>0.05) for all other nutritional parameters under consideration. Similarly, regardless of the difference in the ensiling periods there were no noticeable changes (P>0.05) in both chemical compositions and in-vitro digestibility coefficients except, of course, for DM & OM of the residues incubated between 30 and 40 days. In other words, there were no net gains in nutritional values by adding extra ten days beyond 30 days of incubations. Interactional effects between straws, rates of EM2 applications and incubation periods for all laboratory quality parameters considered in this particular studies were very weak and happen to remain non-significant (P>0.05).

Table3. Response of crop residues to different rates of EM2 applications and durations of incubations

Variables	Average nutritive value expressed as % DM								
	DM	Ash	OM	CP	NDF	ADF	H-cell.	Lignin	DOMD
1 Lt/Kg DM	92.58[a]	9.45[b]	90.55[a]	2.49[a]	76.48[a]	56.68[a]	19.80[a]	8.77[a]	46.23[a]
1.5 Lt/Kg DM	92.17[b]	9.97[a]	90.03[a]	2.44[a]	76.74[a]	56.97[a]	19.78[a]	8.90[a]	45.76[a]
Mean ± SEM	92.38 ±0.01	9.71 ±0.01	90.29 ±0.01	2.47 ±0.01	76.61 ±0.01	56.83 ±0.03	19.79 ±0.01	8.84 ±0.05	45.50 ±0.13
30 days of ensiling	92.04[a]	9.85[a]	90.15[a]	2.45[a]	76.72[a]	56.70[a]	20.01[a]	8.87[a]	45.50[a]
40 days of ensiling	91.71[b]	10.23[a]	89.77[b]	2.49[a]	76.50[a]	56.94[a]	19.57[a]	8.69[a]	45.49[a]
Mean ± SEM	91.88 ±0.30	9.72 ±0.09	90.29 ±0.10	2.47 ±0.01	76.61 ±0.02	56.82 ±0.02	19.79 ±0.04	8.78 ±0.29	45.50 ±0.01
Straw X EM2 X Incubation	0.103	0.106	0.106	0.073	0.917	0.231	0.554	0.138	0.061

Means with different superscripts along a column are significantly different (P=0.05)

The fact that interactional effects were non-significant has led to the decision to consider the three independent factors for the different quality parameters considered. Accordingly, the absence of statically detectable nutritional quality difference (P>0.05) for EM2 application rates can lead us to further recommendation of EM-2 at the rate of 1lt per kg dry straw mass for use on a wider scale at an on-farm level. More over, the nutritional quality of the residues treated with EM2 and subjected to incubation at two different ensiling periods (30 and 40 days) didn t happen to show any statistically (P>0.05) appreciable differences implying the need to consider 30 days of ensiling periods for EM2 treatment of cereal crop residues under field conditions. Thus considering both factors 1lt EM2/kg dry residue weight incubated for a period of 30 days can be recommended for use on a wider scale under on-farm conditions in the central highlands of Ethiopia. Since probiotic use of EM for crop residue improvement is a recent phenomenon as compared to different strains of lactic acid bacteria and fungi that have deeply studied for the last several decades literatures supporting the EM treatment option both at a laboratory and on-farm condition were quite meager.

Chemical Compositions of Experimental Feed Ingredients

The chemical compositions of feeds used for feeding trial in the present study are shown in Table 3. Higher CP continents were observed for the concentrate mix. The change in CP contents brought about by EM-2 treatment compared to the untreated straw would need to be highly appreciated. The untreated barley straw used in this study contained 27.6%, 31.7%, 15.6% and 27.6% more NDF, ADF, Hemi-Cellulose and Lignin content on DM basis than the treated barely straw, respectively. In this regard, El-Marakby (2003) for a treated wheat straw with white rot fungus *Agaricus bisporous* noticed substantial reduction in the contents of NDF by 45.1%, ADF by 31.5%, and hemicellulose by 96.3%. Samsudin, *et al.* (2013) was also able to note significant differences (P<0.05) among the EM treated rice straw and untreated rice straw in DM, OM, CP, NDF, ADF, and cellulose contents.

Table 4.Chemical compositions and in-vitro digestibility of experimental feed ingredients (% DM basis)

Feed type	DM	OM	CP	DOMD	EME (MJ/kg DM)	NDF	ADF	HC	Lignin
EMTBS	90.09	89.93	4.95	51.7	8.27	57.97	40.66	17.31	8.03
UTBS	93.4	92.39	2.30	33.1	5.29	80.05	59.56	20.49	11.05
Concentrate	89.0	92.10	20.0	68.0	10.88	40.00	21.30	18.70	6.51

EMTBS = EM treated barley straw; UTBS=untreated barely straw; HC=hemicellulose; OM= organic matter; CP= crude protein; ADF=acid detergent fiber; DM=Dry matter; NDF=Neutral detergent fiber; MJ=Mega joule; IVOMD =*Invitro organic* matter digestibility; EME= Estimated metabolizable energy

The level of DOMD and Estimated metabolizable energy (EME) contents observed for the treated barley straw was much higher than that for the untreated barely straw. However, the values were much lower compared to that observed for the concentrate mix used in this study. Akinfemi and Ogunwole (2012) also reported that EME was highest for the fungal treated rice straw than the untreated residue. Similar observations by Sommart *et al.* (2000); Nitipot and Sommart (2003) indicated that *in-vitro* dry matter and organic matter digestibility were higher for biologically treated straws than that of the untreated residues. Due to EM2 treatment the value for CP was almost doubled over the untreated residue. El-Banna *et al.* (2010a) treated potato vines with *Lactobacillus acidophilus* and reported similar improvement in CP content from15.8 to 18.5%. The improvement in CP constituent would not only sufficient enough to meet the requirement for crude protein for ideal ruminal fermentation emphasizing the need to consider additional protein supplement from the concentrate diet of lactating crossbred cows. The improvement made in cell wall fraction over the untreated residue of barley straw was quite immense. According to Singh and Oosting (1992) roughages with NDF content of 45-65% are generally categorized as a medium quality basal feed, while feeds with NDF below 45% are grouped as high quality feeds. Since intake and digestibility limitation with untreated residue can somehow be improved with EM treatment (table 5 & 6) additional saving in the daily allowance of concentrate can even be envisaged from lactating crossbred cows maintained on a basal diet of EM-2 treated crop residues.

Daily Feed and Nutrients Intake

The values for voluntarily feed and nutrient intakes of experimental cows are presented in table 5. There were considerable changes (P<0.05) in the daily basal feed intakes between the groups that fed with the treated and untreated barley straw residues. Despite clear difference in the daily allowance of concentrate as we move along the treatment set-up differences were non-significant (P>0.05) for cows under dietary treatments receiving the treated barley straw. Experimental cows receiving the treated barely straw as a basal diet consumed on average 6.62kg per day while those on the untreated residue consumed 1.76kg less barley straw on a daily basis. Daily allowance for concentrate and total dry matter intakes were significantly differing (P<0.05) both among the treatment groups that were receiving the treated residues and when these groups were compared with cows receiving the control diet.

The increasing trend (P<0.05) in the daily concentrates allowance didn't happen to influence basal feed intake among cows that received the treated barley straw. This may be due to the fact that major nutrient intakes across the cows receiving the treated straw diet might have addressed the requirement for the observed daily basal intake. However, total feed DM intake followed the rate of concentrate supplementation across the dietary treatments. It can thus be said that the improvement in the daily basal feed intake over the untreated residue seem to have been much influenced by the changes in the chemical compositions and organic matter digestibility (see table 2 & 4) of the residue brought about by EM2 treatment and the corresponding daily nutrient intakes and digestibility from the total diet.

Daily Nutrient intakes followed same trend as for the total DM intake. Differences were, in general, significant (P<0.05) both among and between dietary treatments with cows on dietary T3, exceptionally consuming considerably higher daily nutrient intakes followed by cows on dietary T2 & T1. Except for ADF intakes the increasing trend for all nutrient intakes followed the increasing trend in the daily allowance of concentrate intakes among cows receiving the treated residue. Improvements in daily nutrient intakes over the untreated residues were 1.73kg (OM), 0.27kg (CP), 0.13kg (NDF) and 31.99MJ (ME). On the contrary, because of the response of ADF residue to EM2 treatment was so marginal (see table 4) average daily intake of ADF fraction by cows receiving the untreated residue as a basal diet was higher by 0.13kg than those cows receiving the treated barely straw residue. Metabolizable energy(ME) intakes differences were highly significant among all dietary treatments (P <0.05) with cows on dietary treatment 3 consuming considerably higher daily ME contents of 15.07, 30.08 and 47.04 compared to that of cows in T2 ,T1 and T4, respectively. All cows in the current trial were, therefore, on the positive energy balance since daily ME requirement across all dietary treatments were sufficiently been met for the mean daily produced milk yield of 6.52 kg if not for the targeted daily milk yield of 8-10 kg according to ARC (1990). In other words, cows on all treatments were on the negative energy balance for the targeted daily milk yield of 8-10kg presumably because the total ration was not fortified with adequate energy sources both quantitatively and qualitatively taking in to account the quality of the basal diet.

The reason for absence of significant difference (P>0.05) for daily DM, OM, CP & NDF intakes between the cows receiving dietary T1 & T4 may be speculated to the fact that cows on the control diet even though consumed as much more concentrate mix per day (0.5kg/lt) as their counterpart cows in T1 (0.3kg/lt) had higher ADF intake that perhaps have affected digestibility and eventually daily intake of the nutrients. Secondly, it may be linked to the assumption that cows that have been fed with the treated straw had more basal feed intake and hence consequently ingested more of the nutrients which can, indeed, simply offset nutrient intakes from larger concentrate intake by the control group.

Using wheat straw and different other crop residues that are microbially treated and fed to different class of animals in China and elsewhere Wu (1996), Chen and Li (1998), Meng *et al.* (1999), and Fazeali *et al*. (2004) reported similar improvements in the daily basal and nutrient intakes for DM, OM, CP, NDF and ADF. Considerable changes in basal, total feed and daily nutrient intakes according to these authors were related to the fact that ensiled crop residues with microbial agents usually have good palatability for ruminants, and thus would be responsible for higher intake. More over according to Mekasha *et al.* (2002) the lower fiber and relatively higher CP contents in the treated residue may be responsible for the improved DM and total DM intakes by ruminants. In many experiments in comparison with ammoniated straw, microbially ensiled residues gave higher intake, faster rate of passage and therefore better performance simply because microbial agents (typically funguses and some bacteria) can effectively attack lignin and cellulose (McCarthy 1986; Fayed *et al.*, 2009 and Mahrous *et al.*, 2009). On the contrary, the finding from this trial is completely in contrast with those reports by (El-Banna *et al.* 2010a; El-Banna *et al.* 2010b; Abd El-Galil 2011) who declared negative responses for daily feed and nutrient intakes from biologically treated crop residue based diets for various classes of animals compared to the untreated residues. These variations can be associated to the difference in the microbial agent used; type of residue subjected to the biological treatment and the difference in the experimental animal unit and/or the environment under which the specific trials were conducted.

Table 5.Dry matter and nutrient intake of lactating crossbred dairy cows

	Treatments				
Intake (kg/day/cow)	T1	T2	T3	T4	SEM
Barely straw	6.65 [a]	6.68[a]	6.54[a]	4.86[b]	0.17
Concentrate	1.72[c]	3.05[b]	4.48[a]	2.84[b]	0.34
Total DM	8.37[c]	9.73[b]	11.02[a]	7.65[c]	0.34
Total OM	7.57[c]	8.80[b]	9.99[a]	7.06[c]	0.31
CP	0.68[c]	0.94[b]	1.22[a]	0.68[c]	0.07
NDF	4.58[c]	5.14[b]	5.67[a]	5.00[bc]	0.16
ADF	3.02[b]	3.28[ab]	3.49[a]	3.39[a]	0.09
ME (MJ/day)	74.72[c]	89.73[b]	104.8[a]	57.76[d]	3.80

[abc] Means with different superscripts within row are significantly different (P<0.05); SEM=standard error of mean; DM = Dry matter; CP = Crude protein; NDF= neutral detergent fiber; ADF acid detergent fiber; ME = Metabolizable energy;

Apparent Digestibility of Dry Matter and Major Nutrients

The results of the effect of EM2 treated barely straw supplemented with concentrate mix on total diet apparent nutrient digestibility of lactating cross breed dairy cows are presented in table 6. Total diet apparent nutrient digestibility appeared to be significant (P<0.05) over experimental cows maintained on the control diet except for DM & OM which was observed to be non-significant both among and between experimental cows receiving the different dietary treatments. Accordingly, experimental cows that have been fed with the treated barley straw as basal diet digested on average 11.89%, 9.52% & 7.57% more CP, NDF and ADF over the cows receiving the control diet per head per day, respectively. Among cows in the intervention group, however, more nutrients except DM & OM on a daily basis were digested by cows receiving dietary T3. Compared to the control group cows on dietary T3 effectively digested more CP, NDF and ADF which was calculated to be greater by 18.6, 13.6 & 10.57 percentage units, respectively on a daily basis.

In general, it can be said that the improvements in apparent nutrient digestibility have been clearly reflected by a more and progressive daily intakes for cows that have been receiving the treated barley straw residue (see table 5). The effect of treatment shall clear be appreciated for cows maintained under dietary T1 that have consumed equivalent or even in some case more basal feed and nutrient intakes while these same cows were still receiving 200gm less formulated dairy concentrate per day compared to cows on the control group. A tendency for the increased apparent digestibility for all nutrients among cows fed with EM2 treated barely straw compared to the control group may be explained by the higher degradability rates of the treated barley straw crop residue in the rumen associated to the delignification process during the ensiling process which renders more cellulose and hemi-cellulose for microbial colonization and fermentations in the rumen. It could also be related to higher dietary total DM intake among the treated residues compared to the control group (see table 5 above).

The result from the current finding is also in par with El-Banna *et al* (2010a) and El-Banna *et al.* (2010b) who reported that the digestibility coefficients of DM, OM, CP, NDF, ADF, hemi-cellulose and cellulose of *Lactobacillus acidophilus and* brown rot fungi *Trichoderma reesei F-418* treated potato vines and SCB were higher than those of untreated potato vines and SCB. Guim *et. al. (*2000) further stated that DM digestibility percentage of EM treated silage resulted significant levels of increment in the digestibility of CP than untreated silage. Moreover, Kholif *et al.* (2005) and Mahrous (2005) in a similar finding to the current trial found that roughages subjected to fungal treatments had increased (P<0.05) digestibility for most nutrients and thus their feeding values as TDN and digestible crude protein (DCP) increased compared with untreated materials.

Crude protein digestibility among all other dietary nutrients was found to be significantly higher (P < 0.05) for cows on dietary T3 which has digested 7.14%, 13% and 21.6% more CP contents per day than cows on dietary T2,T1 and T4, respectively. This higher digestibility percentage of CP for cows under T3 might have something to do with the higher intake of concentrate mix and hence CP intake (see table 5 above) compared cows on the remaining treatments. Maseaki *et al.* (1992) noticed that biologically treated straws as well as other fibrous roughage resulted in an increase of CP content and digestibility.This result is also in line with the contention given by Gado *et al. (*2006); Khattab *et al. (*2011), that biological treatment of poor quality roughages usually result in marked increases in their CP content digestibility when the treatment conditions were appropriate.

Data analysis from the current trial showed that, for the cows receiving the intervention diet the cell wall constituents digestibility were significantly increased (P<0.05) over the untreated residues. These results are in agreement with those obtained by Abd-Allah (2007) with biologically treated corn cobs by *T. ressei* and Mahrous *et al.* (2009) compared with untreated materials. The improvement in cell wall digestibility coefficients as a result of biological treatments according to Nsereko *et al.* (2002) and Ali, (2005) may be due to the effect of increasing numbers of cellulolytic bacteria and fungi in the rumen, which may be responsible for the stepwise hydrolysis of cellulose to glucose.

Table 6.Feed DM & Nutrient Apparent Digestibility of Experimental Cows

Apparent digestibility (% DM basis)	Treatments				
	T1	T2	T3	T4	SEM
DM	47.65 [a]	51.17[a]	52.57[a]	39.91[a]	4.19
OM	51.09[a]	54.51[a]	55.92[a]	45.01[a]	3.89
CP	50.01[b]	55.87[a]	63.01[a]	44.412[c]	4.44
NDF	43.93[b]	45.32[b]	50.38[a]	37.02[c]	4.2
ADF	34.62[b]	38.33[a]	40.98[a]	30.41[c]	4.38

[abc] *Means with different superscripts within row are significantly different (P<0.05)*

Milk Yield and Compositions

During the entire experimental periods there were no any unusual abnormalities or health problems observed on all the experimental animals due to the effect of feeding EM2 treated barely straw. Results of the effect of dietary treatments on mean daily milk yield and compositions are presented in Table 6. There were significant differences (P < 0.05) in milk yield both among and between the cows fed EM treated and untreated barely straw basal diet. On a daily basis cows that were maintained on dietary T3 produced extra daily milk of 0.55, 0.65 and 1.07 kg over those cows that were maintained on the remaining dietary treatments of 1, 2, and 4, respectively. The extra daily milk produced by cows under T3 may be justified by the relatively larger daily concentrate intake and hence protein and energy intake per head of the animal that may be over and above than supplied by the remaining treatments. Cows receiving dietary T1 produced significantly (P<0.05) more daily milk yield (0.42kg/day) over the cows receiving the control diet and the same amount of daily milk yield (P>0.05) as cows on dietary T2.

The most interesting finding from the current study was the saving in the daily concentrate allowance of 200 gram per head of cows under T1 over those cows maintained under dietary T2 & T4. When the efficiency of milk production is compared taking in to account the daily concentrate allowance for each treatment cows which were receiving T1, T2, T3, and T4 consumed 0.267kg, 0.466kg, 0.632kg and 0.472kg, respectively for each kg of milk production. This implies cows under T1 were efficient and more economical since less concentrate (0.267) was consumed to produce a kg of milk. On the contrary, cows maintained under dietary T4, even though, produced higher milk yield per day have consumed relatively more concentrate for each kg of milk produce. Before embarking on recommending any one of the dietary treatments it seems, however, mandatory to look in to the economics of the feeding so that recommendations are set based on both the biological and economic response of the cows.

The higher daily milk production among the cows that received the intervention diet can be speculated to the higher feed and nutrient intake obtained from the treated barley straw basal diet. Fazaeli *et al*. (2002) studied the effect of fungal (*Pleurotus ostreatus* coded P-41) treated wheat straw in the diet of lactating Holstein cows at 0, 10, 20 and 30% levels. Similar to the present finding they found as the daily milk yield and its composition were not affected by consumption of increasing amount of dairy concentrate. Fazaeli *et al*. from his experiment in 2004 further noted that inclusion of fungal treated straw up to 30% of the total mixed ration in late lactating Holstein cows improved the nutrients digestibility and also noted an increase in fat corrected milk yield by 13%. Some other researchers (Moawd, 2003; Khattab, *et al.* 2011) with their similar experiments that used biologically treated wheat straw and/or rumen contents fed *ad libtumly* to either lactating sheep or goats reported same findings that agree with the finding of the current trial for milk yield and compositions compared to that recorded for the untreated residues.

Cows fed with the EM treated barely straw produced higher milk fat content ($P<0.05$) than the cows in the control group. The higher fat percentage ($P<0.05$) by cows on T3 over those cows that were receiving dietary T1 & T4 can be associated to higher total DM, nutrient intake and digestibility (see table 5 & 6). Nahla *et al*. (2014) also indicated that lactating cows fed diets based on microbial ensiled straw had increased milk and fat-corrected milk yield, and slightly higher milk fat percentages compared with diet of untreated straw. Moreover, Kholif *et al.* (2014) reported increased fat contents for *Pleurotus ostreatus* treated rice straw fed lactating Baladi goats (38 and 40 *vs*. 34 g h-1 d-1) compared with those fed untreated rice straw. The improvement in fat contents of the milk produced from lactating animals fed with feeds treated with biological agents according to these researchers was perhaps linked to the increased levels of milk conjugated linoleic and unsaturated fatty acids obtained from the increased daily intake of the treated barley straw intake. Milk protein percentages also varied significantly ($P<0.05$) with cows receiving T2 & T3 having the highest protein percentage unit over those cows that were receiving the control diet. Increased dietary CP intake from the daily concentrate allowance (see table 5) might have helped experimental cows in these group generate the observed difference in milk protein. Phipps (1994) attributed higher daily milk yield and protein concentration to the high protein intakes of lactating cows. On the other hand, no considerable difference ($P>0.05$) was noticed both among the cows that were receiving EM treated barley straw as intervention basal diet and when similar groups were compared with the control group for milk lactose and total solids. It is unclear why milk sugar (lactose) was not affected both among and between the different dietary treatments despite the marked differences observed in the daily concentrate allowance of the cows existing under the different dietary treatments. It is also hardly possible to explain the absence of significant difference among all dietary treatment for milk total solids while still considerable improvements were made to other compositional parameters except for milk lactose. To this end, negative responses in daily milk yield and qualities have also been reported elsewhere. Kholif *et al.* (2014) replaced berseem clover with *Pleurotus ostreatus* treated rice straw at 25 and 45% of diets contained (CFM and berseem clover at 1:1 w/w) and found that feeding Baladi goats on treated rice straw at 25 and 45% had lowered milk yield (954 and 802 *vs*. 966 g h-1 d-1) compared to those fed un treated rice straw. Milenković *et al.* (2004) also found that replacing diets of Holstein Frisian cows with 2 and 4 kg of *Pleurotus ostreatus* spent substrate decreased milk yield (*P*>0.05) with the increase of participation of dry matter in dry matter of a meal. The content of solids not fat, proteins and lactose in milk decreased with increasing the level of the substrate in a meal, while the fat amount in the same trial alone was increased.

Table 7.Milk yield and composition of lactating crossbred cows

Parameters	Treatments				SEM
	T1	T2	T3	T4	
Milk yield (kg/day)	6.440[b]	6.540[b]	7.09[a]	6.02[c]	0.18
Milk compositions					
Fat (%)	3.85[b]	3.92[ab]	4.04[a]	3.71[c]	0.065
Protein (%)	2.97[ab]	2.98[a]	3.09[a]	2.91[b]	0.05
Lactose (%)	5.00[a]	4.76[a]	4.91[a]	4.88[a]	0.14
Total solids	12.41[a]	12.40[a]	12.45[a]	12.43[a]	0.10

[abc] *Means with different superscripts within row are significantly different at (P<0.05)*

Economic Return Obtained from EM2 Treated Barely straw Feeding

Economic returns were calculated for the different groups of animals based on current price data collected for each input and out price from local markets around Holetta town (Table 8). A partial budget analysis measures those items of income and expenses that change (Stemmer *et al.*, 1998). Therefore, the costs of EM2 treatment per kg straw mass, concentrate feed ingredients and the cost for treated barely straw consumed by the animals in the different treatment group were considered as varying costs while all other costs (labor for routines, medications, electricity, water etc.) were ignored since they remained constant over all the dietary treatments.

Cost benefit analysis from the table below indicated that experimental cows receiving the control diet were on the better position in terms of the gross amount of return obtained from an individual cow per day. This gross return when calculated over cows maintained on the remaining dietary treatments was more than double, i. e. 31.83, 35.83 and 33.95 more

Ethiopian birr per day over those cows maintained with the treated barely straw based diet of T1, T2 and T3, respectively. Among cows that were receiving the intervention diet differences in terms of gross and net return over control cows were, in general, not very much appreciable. Cows on dietary T1, however, generated more gross and net return over the remaining cows other than those on the control diet. More economic return by control cows can be justified by the rising cost of straw treatment with EM2 than it was originally anticipated. Moreover, the difference in the daily basal feed intake previously observed in table 5 and the resulting milk yield per day of cows receiving the intervention diet were not big enough to offset the costs for straw treatment compared to cows receiving the untreated residue. On the other hand, the relatively higher gross and net return per cow per day of cows in T1 group compared to same cows receiving treated straw based diet in T2 & T3 might have something to do with the reduction in the daily allowance of concentrate feed by 0.2 and 0.4 kg/day over same treatments, respectively. Taking the current economic benefits in to consideration feeding cross bred lactating cows with EM treated barley straw over the untreated residue seems quite unlikely unless research has come with some other alternative strategies that dramatically cut the present cost of straw treatment with EM-2 microbial solution.

In view of the above, the economic returns from the intervention diets may be higher if the positive long-term impact of EM treatment on general body condition and reproduction are also taken into account. Moreover, considering the present cost of straw treatment with EM and the market price of milk, feeding EM treated straw may be so much economically attractive if cows of high milk production potential in early lactation are fed with EM treated straws of relatively poorer quality but as the same time cheaper on the local market.

Table 8. Economic return/ cow/day of experimental cows fed the different dietary treatments

Variables	T1	T2	T3	T4
Cost variables				
EM-UBS				10.11
EM-TBS	58.39	58.65	57.42	
Concentrate	6.15	10.94	16.07	10.19
Total variable cost	64.54	69.59	73.49	20.30
Income variables				
Milk sale	67.62	68.67	74.45	63.21
Dung cake sale	24	24	24	16
Total income	91.62	92.67	98.45	79.21
Gross return	**27.08**	**23.08**	**24.96**	**58.91**
Net return /control diet	**-31.83**	**-35.83**	**-33.95**	

Assumptions

- Estimated labor cost per day was 70 birr
- Cost of 1kg treated barley straw was 8.78 birr
- An average feacal dry matter output of 4.01kg & 5.04kg for the control and cows on the intervention diets. With that assumption a cow on the control diet produced around 8 dung cakes/day while cows on the intervention diet produced around 12 dung cakes on same date.
- Sale price of a dung cake was 2 birr
- Sale price for a liter of milk was 10 birr

Summary and conclusions

In conclusion, nutritive value, intake and digestibility of crop residues can be considerably improved when a liter of EM2 solution was applied against the dry mass of a kg of the residues. Moreover, daily milk production response among the cows fed with EM2 treated barley straw basal diet can be substantially improved when lactating cows were supplemented with a dairy concentrate equal to and/or above 0.3kg/liter/day. Owning to the inflating cost of straw treatment presently it won't be economical to feed EM treated residues compared to untreated residue to lactating cows of low milk yielding potential. It is, therefore, recommended that future research work shall focus on minimizing total feed cost by: feeding EM treated residue to relatively highly responsive high producing cows, of course, by reducing cost of straw treatment mainly through reconstituting the residues with water prior to EM treatment. That way the amount and cost of EM2 used per kg straw mass can be drastically reduced. The cost of treatment and hence of feeding can further be cut to a significant level if the initial purchase price of preferred residue for EM2 treatment and ensiling is relatively cheaper. So under local condition it worth to consider wheat straw than barley and teff straw.

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