Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.13, 2016 www.iiste.org

Effects of Replacement of Formulated Concentrate Mix with Cowpea (Vigna Unguiculata) Hay on Feed Utilization, Milk and Milk Composition of Lactating Horro Bred Cows Fed Natural Grass Hay

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Abstract
The experiment was conducted at Bako agricultural research center with an objective to evaluate the replacement effect of formulated concentrate mix with cowpea hay in the daily ration of lactating Horro cows fed natural grass hay. Five cows of same milk yield, body weight, age of lactation, but differing parities were arranged in 5x5 Latin square design. The animals were provided with natural grass hay based diet adlibitum and supplemented with cowpea hay 0 % (T1), 25 % (T2), 50% (T3) 75% (T4), 100% (T5) to replace concentrate mix. Results of chemical analysis of the experimental feeds indicated that cowpea hay had comparable nutritive value with concentrate mix. The daily dry matter (DM) and crude protien (CP) intake were significantly ($P<0.05$) differ among the treatments with the highest intake observed when cows were fed 50% cowpea hay (T3). Apparent DM digestibility of T3 (60.65%) was higher ($P<0.001$) than T5 (47.18%). The milk yield were significant differences among the dietary treatments with lower mean milk yield recorded in T4 and T5 as compared to T1, T2 and T3. This implies that cowpea hay can replace up to 50% concentrate mix without any significant reduction in milk yield. Therefore, cowpea hay can be replace a concentrate diet up to 50% of replacement without significant reduction in milk yield and live weight of lactating cows fed a basal diet of natural grass hay.
Keywords: Digestibility, Local breed, Intake and Milk quality

1. Introduction

In developing countries livestock sector is highly dynamic, to meet rapidly increasing demand for livestock products. This demand is largely driven by human population growth, income growth, urbanization and the production response in different livestock systems. The main constraint facing small scale dairy farmers in smallholder mixed farming, pastoral and agro pastoral production systems across East Africa is the inability to provide sufficient quantity and quality feeds to their livestock on a consistent basis (Hall et al 2008).

The major feed resources in Ethiopia for ruminants are natural pasture and crop residues, which are categorized as poor quality roughage with low intake (Berhanu et al 2009), due to their tough texture, poor digestibility and nutrient deficiency (Mupangwa et al 2002). Moreover, the importance of natural pasture as source of feed resource is gradually declining as a result of the expansion of crop production, redistribution of grazing lands to the landless and land degradation (Mulat 2006).

Protein intake is improved by both the addition of a higher protein source feed and by increasing the availability of protein through increased digestibility of the lower quality forage. The use of industrial by-products of oil crops as supplement on low quality roughages are very expensive and unaffordable for rural farmer, so as alternative solution forage legumes is another option as source of protein. Improving the use and nutritional quality of natural grass hay by supplementation of forage legumes hay is important to enhancing dairy cattle productivity.

Cowpea *(Vigna unguiculata)* is an important component in mixed systems and is valued for its potential to produce high levels of hay/fodder for livestock. Studies indicated that cowpea hay addition improves nutrient supply and growth of livestock over the use of low quality forages alone but degree of weight change varies relative to total nutrient supply (Baloyi et al 2008). One benefit of the use of cowpea hay as a supplement is the provision of nitrogen to the rumen microbes, allowing them to improve utilization of the low quality forage.

Therefore the objective of this study was to determine the amount of cowpea hay that can replace the recommended amount of formulated concentrate mix on voluntary feed intake, feed conversion ratio and milk yield and composition of lactating Horro cows fed natural grass hay as basal diet.

2. Materials and Methods

2.1. Description of the Study Area

BARC is located in Oromia Regional State West Shoa zone at about 257 km from the capital city Addis Ababa on the way to Nekmete town. The centre is located at 8 km from Bako town. The altitude of the research centre is 1650 masl and lies at about 09°6’N latitude and 37°09’E longitude.

2.2. Experimental Animals and Management

A total of five Horro breed cows were used for the experiment. Experimental cows with similar lactation performance, same early stage of lactation, similar body weight, but with different parities were selected from the total dairy herd available in BARC. All cows were weighed and drenched with broad-spectrum anti-helminthics (Albendazole 500 mg) prior the commencement of the experiment. The calves were separated from their dams five days after parturition and reared according to the standard calf rearing procedures of the research centre. The cows were placed in an individual pen in a well-ventilated barn with concrete floor and appropriate drainage slope and gutters and stall-fed. The cows were hand-milked twice daily at approximately 12-hour intervals in milking room.

2.3. Feed Preparation and Feeding

Cowpea (*Vigna unguiculata*) and natural grass hay were harvested at appropriate stage and dried, chopped and stored under a hay shade and used throughout the experimental period. The basal feed offer was adjusted daily by allowing 20% of refusal from previous day's intake. The quantity of concentrate mix offered daily was at the rate of 0.5 kg/l of milk produced by each cow and offered with equal portions during the morning and evening milking time, respectively. The amounts of cowpea given were calculated depend on the amount of CP in the concentrate diet or isonitrogeneous. Representative and composite samples of all experimental feeds were taken for laboratory analysis.

2.4. Experimental Design, Treatments and Measurements

At the beginning of the experiment, five cows were randomly assigned in a switch over 5X5 Latin square design. There were five periods each consisting 30 days. During the first 15 days of each period, animals were acclimated to the experimental diet and the remaining 15 days were used to collect data. Hence, the experiments took 150 days; being started in December 2013 and finished in April 2014. The experimental animals were initially randomly allotted to one of the five dietary treatments given below. The concentrate mix is (49.5% maize grain + 49.5% noug seed cake + 1% salt). Treatments were:
T1: Concentrate mix (100%) (0.5 kg/l of milk) + Natural grass hay *ad libitum*
T2: Concentrate mix (75%) + Cowpea hay (25%) + Natural grass hay *ad libitum*
T3: Concentrate mix (50%) + Cowpea hay (50%) + Natural grass hay *ad libitum*
T4: Concentrate mix (25%) + cowpea hay (75%) + Natural grass hay *ad libitum*
T5: Cowpea hay (100%) + Natural grass hay *ad libitum*

The basal feed was offered *ad libitum* at a 20% refusal rate and the offer was adjusted every four days. The quantity of concentrate mix offered daily was at the rate of 0.5 kg/l of milk produced by each cow and it was offered with equal portions during the morning and evening milking. Adjustments for concentrate offer was made at the end of each period and for each treatment based on the actual milk produced. The amounts of cowpea hay given was depending on the percentage of crude protein in the concentrate feed and equivalent CP contents were adjusted depending on the CP in the formulated concentrate mix and CP in the cowpea hay. Feed offered and refused was measured and recorded for each cow to determine daily feed and nutrient intake.

The daily milk yield data of individual cows was taken using a Salter balance. About 100 ml milk sample in the morning and afternoon was taken twice every week during the experiment from each cow into a glass measuring cylinder (100ml capacity) after the milk was thoroughly and gently mixed. Body weight was recorded for two consecutive days at the beginning and end of each experiment period for each treatment to monitor body weight change that may occur as a result of dietary treatments.

2.5. Apparent Digestibility

Apparent digestibility of the diet used in each treatment was determined using total feacal collection methods for a period of 5 consecutive days at each period. Farm personnel were assigned around the clock to scoop faeces into plastic buckets as soon as the animals defecated. Urine contamination was minimized by frequent washing of the concrete floor with high pressure running water using a plastic water tube. Individual cow's faeces were weighed every morning before 08:00 hours and before fresh feeds were given to the animals. After weighing, the faeces from each cow were thoroughly mixed and a sample was taken and placed in polyethylene bag. Composite samples of about 1% of the daily collected fecal samples were mixed and stored as one sample in a deep freezer (-20 ^{o}C) until the end of the collection period. At the end of the collection period, the 5 days pooled samples were subsequently thawed and mixed thoroughly and two subsamples taken. One sample for estimating DM was oven dried at 105^{o}C for 24 hours, while the other sample was 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 natural grass hay, cowpea hay, concentrate mixture and faecal DM output were analysed to determine DM, OM, N, NDF, and ADF digestibility.

2.6. Invitro Organic Matter Digestibility

The two stage rumen inoculums-pepsin method of Tilley and Terry (1963) were used to determine IVOMD. Rumen liquor was collected from ruminally festulated steers and transported to the laboratory using thermos flasks that had been pre-warmed to 39 ^{0}C. Rumen liquor was taken in the morning before animals are offered feed. A duplicate sample of 0.5 g of each were incubated with 30 ml of rumen liquor and a buffer in 100 ml test tube in water bath at 39 ^{0}C for a period of 48 hour for microbial digestion followed by another 48 hour for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid were incubated in duplicates for adjustment.

Natural grass hay and cowpea hay samples were taken directly from the store of hay every two weeks after the hay chopped to represent the actual feed consumed by the cows. Samples of concentrate were taken from total concentrate mix. Similarly, feed refusals samples were taken four times per week for two weeks for each treatment and composited for each treatment from which sub-sample was taken for analysis per treatment. Partially dried samples were ground using Cyclo-Tec mills to pass 1 mm sieve size for proximate, detergent, and *invitro* digestibility analysis and kept at room temperature in sealed plastic bags until they were used for analysis. The milk samples were composited per cow and per treatment and two times samples were taken per period for chemical analysis.

All samples of feed offered and refusals and faeces were analyzed for DM, ash, N (Kjeldahl-N) according to AOAC (1990). Organic matter (OM) was determined as 100-ash. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined by the methods of Van Soest and Robertson (1985). *Invitro* organic matter digestibility of feed offered and refusal was determined using the procedures outlined by Tilley and Terry (1963). The milk samples were used to determine percentage fat, protein and solid not fat (SNF) by Ultrasonic Ekomilk Analyzer (30 w Bulteh 2000, Bulgaria), which have the capacity to measure 20 – 25 samples per hour. Calcium and phosphorous content of the offered feeds were analysed by atomic absorption spectrophotometry and colorimetry (AOAC 1995) respectively.

2.7. Statistical Analysis

Voluntary DM and nutrient intakes, live weight change, milk yield and compositions, and digestibility were subjected to GLM procedure for Latin Square Design using Statistical Analysis System (SAS 2002) and Regression analysis was done with excel program in Microsoft office 2010. Treatment means were separated using Least Significant Difference (LSD). The models used for the analysis of data were: $Y_{ijk} = \mu + C_i + P_j + T_k + E_{ijk}$, Where; μ = Overall mean; Ci = Cow effect (parity); Pj= Period effect; Tk = Treatment effect; Eijk = Experimental error

3. Results and discussion

3.1. Chemical Composition of Experimental Feeds

The DM content was almost similar for all ingredients used in the present study. The OM content was relatively higher in maize grain, followed by the concentrate mix and least in natural grass hay. The neutral detergent fiber concentration showed much variation with the highest value recorded for the natural grass hay followed by cowpea hay and the concentrate mix, respectively.

Table 3: Chemical composition, *in-vitro* dry matter digestibility and metabolizable energy content of experimental feeds (% for DM and %DM for other chemical composition values)

Feeds offered	DM	OM	CP	NDF	ADF	ADL	EME (MJ Kg^{-1} DM)	IVDMD	Ca	P
NGH	92.62	88.4	11.72	72.46	48.68	6.32	7.98	49.90	0.12	0.99
Cowpea hay	90.64	89.76	21.03	47.38	31.42	5.4	9.67	72.9	1.03	0.22
Maize grain	89.2	98.3	8.4	5.6	2.40	-	15.6	97.50	0.02	0.92
NSC	92.00	89.00	31.7	32.3	29.8	10	11.1	69.20	0.35	0.83
Concentrate	92.74	94.85	25.27	32.67	17.13	2.10	12.2	70.18	0.28	1.60

EME= Estimated Metabolisable Energy (0.016*DOMDM); NGH=Natural Grass Hay; NSC= Noug Seed Cake

The supplements (concentrate mix and Cowpea hay) have the higher CP and lower NDF concentrations relative to natural grass hay. The low levels of NDF in both supplements are indicative of high cell soluble matter. The ADF fraction in cowpea hay was slightly higher than that observed for concentrate mix. The IVDMD of cowpea hay (72.9%) observed in the current study lies within the range (53.2-73.6%) and greater than the mean (66.8%) reported by Seyoum (1995) for most herbaceous legumes. The IVDMD of cowpea hay is greater than the IVDMD reported for tropical (56.6%) or temperate legumes (60.7%) (Minson and Wilson 1980). This might have resulted from the stage of harvest and loss of nutrients during the hay making process in the present trial. Based on chemical and digestibility values suggested by Singh and Oosting (1992), both supplements used in the present study can fully replace each other. Thus, there is an enormous potential for cowpea hay to be used as a supplement to low quality basal feeds.

3.2. Dry Matter and Nutrients Intakes

Dietary treatments were significantly ($P<0.05$) affected feed intakes of the cows. Accordingly, replacement of concentrate with cowpea hay at a rate of 50% had significantly ($P<0.05$) increased total DM intake over those cows, which have received cowpea hay at other rate of replacement.

Table 2. Feed intake of Horro cows fed ad libitum of natural grass hay and supplemented with cowpea hay as a partial replacement to concentrate mix.

Parameters	Treatments						
	T1	T2	T3	T4	T5	SEM	SL
Dry matter intake							
Total DM (kg/d)	5.53[ab]	5.49[ab]	6.0[a]	5.38[ab]	4.86[b]	0.36	0.03
DMI (% BW)	2.64	2.63	2.91	2.61	2.43	0.21	ns
Nutrient intake							
OM (kg/d)	5.07 [ab]	5.03 [ab]	5.51[a]	4.88 [ab]	4.37[b]	0.35	0.04
CP (kg/d)	0.81[ab]	0.81[ab]	0.8965[a]	0.78[ab]	0.64[b]	0.06	0.03
ME (MJ/d)	36.06	40.24	40.028	44.85	40.64	3.83	ns
NDF (kg/d)	3.20	3.61	3.32	3.75	3.77	0.35	ns
ADF (kg/d)	2.38	2.32	2.5301	2.29	2.21	0.16	ns
ADL (kg/d)	0.33	0.32	0.35	0.30	0.29	0.024	ns

[a-c]means within rows having different superscript are significantly different at; (*) = P<0.05; SL = significance level; SEM = standard error of mean; ns = not significant

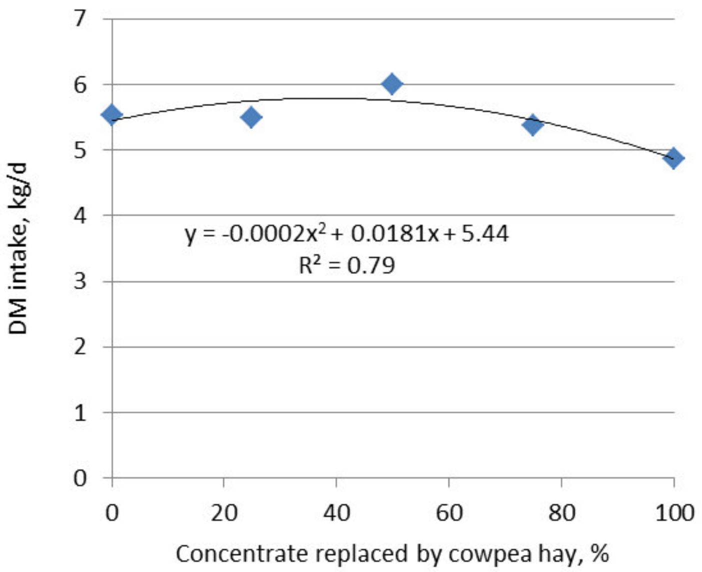

Figure 1. Effect of level of cowpea hay in the diet of total dry matter intake

Treatment effects on crude protein intake (CPI) were found to be significant ($P<0.05$) among the 50% cowpea hay supplemented and 100% cowpea hay supplemented group. Increasing levels of cowpea hay in the total diet didn't result in a significantly ($P>0.05$) higher level of CPI though; the overall CPI is much higher than the projected CP requirement (ARC 1990). The CPI was larger than expected to meet the CP requirement of the cows for both the observed (2.95kg d^{-1}) and the projected (8-10 lit/day) (ARC 1990) milk yield. In general, the improved CPI with cowpea hay -supplemented groups T3 (50% cowpea hay replaced) might have been attributed to the combined effect of cowpea hay with the concentrate mix.

As a rule of thumb, addition of forage legume to low nitrogen content basal diet will increase the nitrogen content of the total diet, which in turn is likely to increase feed intake and the rate of degradation of the basal diet in the rumen (Topps 1997). This, therefore, explains why forage supplementation has increased total DM intake for natural grass hay based treatments comparable to the control diet (T1) in the present trial without significantly ($P>0.05$) reducing the basal feed intake. The numerically increased DMI obtained for T3 might have arisen from the more balanced intakes of both CP and ME that have led to a more efficient utilization of the fibre in the total diet. This is in agreement with other studies (Mpairwe 1998).

The highest MEI (44.85 MJ/head/day) obtained for 50% cowpea hay replacement of concentrate mix is far from the estimated daily ME (97.6 MJ/head/day) requirement of lactating cows weighing 400 kg and producing 8-10 kg milk of 4.5% butter fat (ARC 1990). Total ME intake across all the treatments were sufficient to meet the daily requirement for ME of cows with a mean daily milk yield of 2.95 kg in the present trial.

Metabolisable energy intake either among the cowpea hay supplemented group, or when this group was compared with the control was found to be non-significant (P>0.05) for all dietary treatments considered. Mpairwe (1998) reported that lactating crossbred cows were found to optimize their energy intakes and OM digestibility when a forage legume (Lablab) was supplemented to a basal diet of oat-vetch and maize-lablab basal diet at a modest level of wheat bran supplementation than when the concentrate alone was offered.

3.3. Apparent Dry Matter and Nutrient Digestibility

Table **3.** Effect of cowpea hay replacement of a concentrate mix on mean daily Apparent DMD, CPD, OMD, NDFD and ADFD of experimental cows fed ad libitum natural grass hay

a-c means within rows having different superscript are significantly different at; (*) = P<0.05; SL = significance level; SEM = standard error of mean; ns = not significant

Apparent digestibility (%)	Treatments						
	T1	T2	T3	T4	T5	SEM	SL
DM	56.46^{a}	57.06^{a}	60.65^{a}	54.43^{ab}	47.18^{b}	2.75	0.04
CP	64.02^{a}	62.34^{ab}	65.40^{a}	59.22^{ab}	50.61^{b}	3.05	0.03
OM	59.58^{a}	59.86^{a}	62.87^{a}	57.03^{ab}	49.86^{b}	2.79	0.02
NDF	46.94	54.31	49.63	51.78	49.96	3.71	ns
ADF	49.74^{ab}	47.57^{ab}	49.74^{a}	44.82^{ab}	43.01^{a}	2.89	0.01

Total DM intake tended to be significant (P<0.05) for T3, when compared to T5 dietary treatments. However, increasing level of cowpea hay seems to have significantly (P<0.01) increased DM intake only up to T3. Thus, a tendency for increased ADMD was observed with replacement by cowpea hay from 25% to 50%. However, further increase in the quantity of cowpea hay replacement from 50% to 75% was not accompanied with numerical improvement in ADMD. Thus, apparent DM digestibility of the total diet was observed to be more optimized when cowpea hay was included at the rate of 50% replacement, without any significant (P>0.05) reduction in the basal feed intake. Therefore, cowpea hay at those levels of concentrate replacement can fairly be compared with the concentrate mix (control) as a supplement to low quality basal roughages without any significant reduction (P>0.05) and substitution effect on basal feed intake. Pathak (2005), in his review, reported ADMD of 48.6% for 3% urea treated wheat straw supplemented with a concentrate mix and a small amount of green forage legume for local cows. The differences could also be attributed to the negative relationship arising as a result of the difference between the amount consumed and digestibility (Chilliard et al 1995).

Treatment effects on CP digestibility coefficient were found to be significant (P<0.05) between the 50% cowpea hay supplemented groups and 100% cowpea Hay supplemented group. CP digestibility was optimized at 50% of cowpea hay replacement. The absence of significant difference (P>0.05) with the control for both CPI and digestibility could lead to a definitive conclusion that cowpea hay could partially replace a concentrate mix in the present trial.

The mean CP digestibility (65.4%) observed in the present study could safely be compared to the mean CP digestibility of 71.5% reported by Mpairwe (1998) for crossbred cows fed low quality basal diets and supplemented with graded levels of lablab hay and wheat bran. In all cases, the variations were assumed to have occurred from the difference in the type and quality of concentrates/forage legumes used as supplements, breed and/or species of the particular animal used in the experiment and the quality of the basal roughage used.

Dietary treatments had significant (P<0.01) effect on apparent acid detergent fibre digestibility (AADFD). Similar finding has also been reported by Bareeba and McClure (1996) in which AADFD digestibility was 42.8% for urea treated maize stover supplemented with 20% alfalfa. In this experiment too, higher levels of cell wall (ADF) digestibility were optimized when the basal material was supplemented with a moderate level of (50%) concentrate replacement.

3.4. Milk Yield and Composition

Milk yield seemed to have declined with an increase in cowpea hay proportion in the total ration. However milk yield is pick at 50% replacement of concentrate mix and also there is no beneficial advantage of increasing cowpea hay in the total ration beyond 50%. There was no significant difference (P>0.05) in daily milk yield between the control and the cowpea hay supplemented group up to 50% level of cowpea hay replacement. The observed lack of difference for milk yield and quality between the control and cowpea hay supplemented groups up to 50% provides sufficient evidence to accept of this study that cowpea hay can partially replace a concentrate mix without any significant reduction in milk yield and quality.

Treatment effects were also non-significant (P>0.05) for milk fat, milk protein, and solids not fat. The value of milk protein is high due to the amount of protein intake. The value of milk fat is also high because of the amount of roughage intake is high since roughage and milk fat has positive correlation. The high level of fat reported in this study (Table 4) compared to other studies for poor quality basal feeds supplemented with forage legumes (Mpairwe 1998) were probably associated with higher and better utilization of dietary fibre (Table 2) from which the precursor for mammary lipid synthesis is derived (Susmel et al 1995).

Table 4. Milk yield and composition, and Live Weight Change of lactating Horro cows fed natural grass hay and supplemented with different proportions of cowpea hay as a replacement to concentrate mix

	Treatments						
Parameters	T1	T2	T3	T4	T5	SEM	SL
Milk yield (kg/d)	3.16[ab]	3.08[abc]	3.31[a]	2.75[bc]	2.43[c]	0.17	*
Milk fat (%)	6.22	6.68	6.11	6.12	6.08	0.29	Ns
Milk Protein (%)	3.35	3.61	3.69	3.49	3.60	0.11	Ns
SNF (%)	9.27	8.64	8.85	8.62	8.66	0.295	Ns
Live weight change g/day)	-58.6	-54.435	-53.58	-52.065	-48.75	5.755	Ns

[a-c]means within rows having different superscript are significantly different at; (*) = P<0.05; SL = significance level; SEM = standard error of mean; ns = not significant

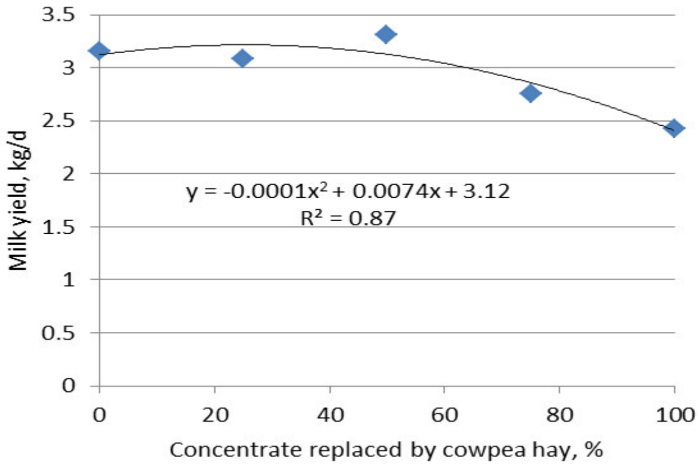

Figure **2**. Effect of level of cowpea hay in the diet on milk yield of Horro breed

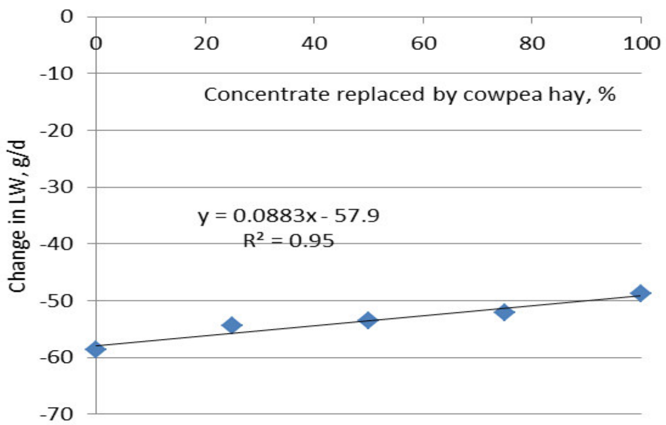

Figure **3**. Effect of level of cowpea hay in the diet on live weight change of Horro breed

3.5. Mean Daily Live Weight Change

Daily mean live weight change of cows on the different treatments is given in Table 4 and Figure 3. Live weight loss was numerically lower in cows on T3 (50% replacement) compared to those cows maintained on T1 and T2. According to Mukassa-Mugerwa (1989), lactating cows will probably lose weight after calving, but weight loss should be minimized through good feeding to allow them to start cycling again to allow annual calving. During the early lactation (first three months after calving) all cows in the current study lost body weight, with a declining trend with advance in lactation.

The variation in live weight change with previous researchers could be explained by the difference in the stage of lactation and genetic potential of the animals used in the experiments, the quality of the basal feeds used and the quality and quantity of supplements used in the respective cases. Garnsworthy (1997) noted that cows in early lactation and those of higher genetic merits partition energy towards milk production at the expense of body fat reserve. This author further noted that cows normally lose 0.5-1.0 kg of body weight each day for the first eight weeks of lactation and this is mostly body fat. Therefore, increased energy intakes at this stage of lactation is expected to result in further increases in milk yield, if the cow's genetic potential has not been reached and/or a reduction in the daily amount of body fat mobilized.

Cows on all dietary treatments in the present study were losing body weight progressively during the first period of the lactation cycle, which can be solely attributed to peak lactations. Cows were still losing body weight after the first period of the lactation cycle, but with a generally declining trend. However, improvements in body weight condition of cows have also been observed for all dietary treatments during the last period of the lactation cycle, all of which could probably be associated with availability of more nutrients in the form of protein and energy from the complete ration. Furthermore, the decreased milk yield during this period must have also contributed to a more diversion of the available nutrients to body fat depositions. Taddele et al (2005) reported a non-significant difference between dietary treatments for milk yield of Boran cows maintained on low quality basal diet (teff straw) supplemented with graded levels of lablab hay replacing a concentrate mix.

4. Conclusion and Recommendations

The results of the present study lead to acceptance of the fact that dry season feeding strategy using high protein farmer-grown cowpea hay in association with natural grass hay can be a significant intervention in a small scale dairy farm. From the present study, it can be concluded that cowpea hay can be replace a concentrate diet up to 50% of replacement without significant reduction in milk yield and live weight conditions of lactating Horro breed cows fed a basal diet of natural grass hay.

5. Acknowledgement

The financial support of Oromia Agricultural Research Institute is gratefully acknowledged. The authors are also grateful to Animal Farm Team member of Bako Agricultural Research Center for facilitating different supports required during the conduct of the research work.

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