Effect of Work, Nutritional Stress and Level of Re-alimentation on the Composition of Compensatory Gains in Draught Oxen

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Abstract

Thirty Highland zebu oxen with a mean weight of 276 (SE ± 14.3) kg and about 6 years of age were blocked by weight into 5 groups of 6 oxen each and within groups allocated to 6 treatments. They worked for 51 days followed by 84 days recovery. Teff straw (Eragrostis tef) and lablab (Lablab purpureus) (TSL) were fed during work and intercropped maize (Zea mays)/lablab (MSL) hay plus wheat bran was fed during recovery. Treatment 1 (T1) composed of ad lib feeding throughout the experimental period (control). In T2, the oxen were fed at 0.8 times their maintenance energy requirement during the working period and fed ad lib during recovery. Oxen in T1 and T2 were not assigned to work. The animals in T3, T4, T5 and T6 were fed ad lib and subjected to work loads involving the pulling of a sledge weighing 27.3 ± 1.6 kg onto which a weight equivalent to 10 % of live weight (LWT) of each animal was placed. The oxen worked for 5 h a day and 6 days per week. During the recovery period, animals in T3, T4, T5 and T6 received 0.7, 0.8, 0.9 and 1 times their estimated ad libitum feed intake based on the actual measurement during the work period, respectively. Feed intake, average daily gain (ADG), dry matter (DMI) and organic matter (OMI) and fat depletion and repletion were estimated for all animals during the working and recovery periods. Rectal temperature, pulse and respiration rates were also recorded during the working period. Work reduced dry matter intake by 1.2 kg/d and caused an average body weight loss of 272 g/d compared to the control (T1). The effect of work (T3, T4, T5, T6) and nutritional restriction (T2) on live-weight change was similar during the work period ($p>0.05$). Work had no effect on dry Matter digestibility (DMD) and organic matter digestibility (OMD) ($p>0.05$). However, improved DMD and OMD were observed in the nutritionally restricted groups. Rectal temperature increased by 0.76° C and 1.24° C after 2.5 h and 5 h of work, respectively. Pulse and respiration rates increased by 21.9 and 40.8 beats/min after 5 h of work, respectively. Empty body fat (EBF) was reduced by work and increased at the end of the recovery period but there were no differences among treatments (T3, T4, T5 and T6). Generally there was a similarity between nutritional and work stressed groups in energy deficit and composition of compensatory gains. On average these animals gained 281 g/d than the control (T1) group at the same level of feeding during the recovery period. It was concluded that nutritional stress and work stress caused similar weight loss and that the optimum quantity of nutrient required for compensatory growth following an intermediate level of work stress is about 0.9 times ad lib feeding (T5).

Keywords: highland zebu, draught, compensatory growth ,feed restriction, nutritional stress

Introduction

Some 200 million cattle and buffalo are used for draught and almost all of these are found in developing countries where they provide about 85 % of the power used on farms (Smith, 1981). These include power for land development, tillage, seeding operation,

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cultural operations, lift irrigation, harvesting, threshing and transport. Draught performance of oxen depends mainly on the quantity and quality of available feed. The seasonality of feed supply also affects the performance of draught animals.

Feed resources for draught oxen during the long dry season are limited both in quantity and quality (Owen, 1985) leading to loss of weight (Sollar *et al*., 1986; Goe, 1987). The extent of body weight loss was estimated between 9 and 18% of their weight to the end of the main rain season (Gryseels and Anderson, 1983). The draught oxen work only between 50 and 70 days per year (Goe, 1987), but consume scarce and valuable feed throughout the year.

The limited quantity and quality of feed resources prior to land preparation and heavy workload immediately following this period make oxen to be weak. One strategy to solve such problem is to diversify the use both as draught and beef animal (Osuji and Capper, 1992). In this case the oxen would be treated as dual purpose, used for a few years (5 to 6) for work, then fattened immediately after their last working season, thus taking advantage of the phenomenon of compensatory growth resulting from re-alimentation (Ryan, 1990) after a period of undernourishment. The other possible option for circumventing this problem is to use multi-purpose crossbred cows for milk and work (Zerbini *et al*., 1993; Takele *et al*., 1995). However, this requires reasonable initial investment.

Animals work output is a combination of draught speed and duration of work. During work there is increased muscular activity that results in rapid increase in heat production. Therefore, there are several changes in physiological parameters. Understanding the physiological responses of animals when stressed due to work or nutrition and the extent of these responses in relation to body weight and condition will contribute to the design of appropriate feeding and management strategies for working.

The objectives of the study were:

1. To establish the quantity of nutrients required to optimize compensatory growth following a moderate level of work stress, and
2. To ascertain whether work stress and nutritional stress resulting in similar levels of energy deficits differentially affect the amount and composition of compensatory gain.

Materials and methods

The experiment was conducted at the ILRI Debre Zeit Research Station that is situated in the central highlands of Ethiopia, 50 km south east of Addis Ababa. The research station is located at an altitude of 1920 meters above sea level with minimum and maximum temperatures of 11º C and 25º C, respectively and bimodal rainfall of 876 mm in which 84 per cent of the rain ring the main rainy season falling between June to August.

Animals and their management

Thirty Ethiopian Highland Zebu oxen with comparable body weight (276± 14.3 kg), and body condition were purchased from the local market and immediately quarantined for 21 days, during which time they were vaccinated against major diseases, dewormed and sprayed against external parasites. The animals were randomly assigned to the six experimental groups. They were individually penned, fed and watered in tie-stall pens in a well-ventilated barn with concrete floor. A preliminary period of 40 days was used to train oxen to carry single yoke and sledge in order to acquaint them with the work implement, each receiving one hour of training per day.

Diets and experimental treatments

The experiment had two periods: work period of 51 effective days followed by a recovery periods of 84 days (12 weeks). A recovery period of 84 days (12 weeks) was chosen based on the earlier reports (Gryseels and Anderson, 1983; Goe, 1987). During the work period the oxen were fed a diet consisting of 65% teff straw (*Eragrostis tef*) (901 g/kg DM CP=34 g/kg) and 35% Dolichos lablab (*Lablab purpureus* '*Rongai*') (844 g/kg DM; CP=150 g/kg). Teff straw and lablab were weighed separately for each animal, thoroughly mixed and offered at 10.00 h to non working animals or immediately after the daily work task. During the work phase (51 days), animals were subjected to work for 5 h/day, 6 days/week. Work comprised pulling of sledges weighing 27.3 ± 1.6 kg onto which a weight equivalent to

0.10 of mass (kg) was placed. These were pulled round a rectangular horizontal surface of about 120 m per round. Each animal was allocated a lane of 2 m wide. The surface area of the metal strip on either side of the sledges that made direct contact with the ground was 500 cm^2. Work period was immediately followed by a recovery period of 84 days. During this period the oxen were fed maize/lablab (904 g/kg DM; CP =82 g/kg) inter-cropped forage supplemented with wheat bran (865 g/kg DM; CP=173 g/kg) that contributed 23% of the diet and was fed separately. Water was provided at all times to the animals that were not subjected to work but the other animals were allowed free access to water after the daily work task. The dietary treatments and status of work during recovery and work phases are given in Table 1.

Table 1. Treatments, number of oxen in each treatment and levels of feed given during work and recovery phases.

Treatment	N	Initial live-weight	Work phase		Recovery phase
			Work status	Feeding level	Feeding level
T1	5	298±14.35	None	Ad lib	Ad lib
T2	4*	282±14.35	None	0.8x Mem**	Ad lib
T3	5	293±14.35	Worked	Ad lib	0.7xAd lib
T4	5	292±14.35	Worked	Ad lib	0.8xAd lib
T5	4*	308±14.35	Worked	Ad lib	0.9xAd lib
T6	5	295±14.35	Worked	Ad lib	Ad lib

**MEm = Maintenance requirement estimated using MAFF (1985); (MEm= 8.3+0.091(LWT of cattle) N = number of animals in each treatment.

*Please note that animals in treatment T2 and T5 were 5 at the initial phase of the experiment. However, two of the animals were excluded from the analysis because they had problems on their legs during the experimental period.

Measurements

Changes in body composition-

At the beginning as well as end of the work period, and mid as well as end of recovery phases in all animals, changes in body composition (fat depletion) were studied using the urea space technique (Kock and Preston, 1979). Urea space was determined by infusing into each animal 200 mg urea/kg live-weight (40 g urea/100 ml of 0.009 NaCl saline) solution (Meissner *et al*., 1977). The solution was filtered using Whatman paper No. 1, transferred into 100 ml bottles and sealed with rubber, autoclaved at 121 °C for 10 minutes and stored at 4 °C until used. The appropriate volume of urea solution was placed in 60ml disposable syringes and infused into the jugular vein through a monoject 18gauge/1.5 needle. Correct placement of the needle in the vein was verified by causing a slight suction. On the average, the infusion process took 2 minutes/animal. Blood sample from the jugular vein was collected into vacutainer tube using a 21gauge/1.5 venoject needle before and 12 to

13 minutes after infusion. The samples were kept on ice until plasma was separated by centrifugation for 6 minutes at 5000 rpm and stored at -20°C for Plasma Urea Nitrogen (PUN) determination. Urea space (US) was calculated from the change in PUN (Kock and Preston, 1979) as follows:

US (proportion of mass) = a*b/(PUN * m * 10); Where

a = Volume of urea infused (ml),

b = concentration of urea solution infused (mg urea-N/100ml), m = live weight,

ΔPUN = difference in PUN taken from blood samples prior to and after urea infusion (mg urea-N/100ml).

Then the equation of Rule *et al*., (1986) was used to estimate empty body fat (EBF) from Urea Space as a proportion of live weight: EBF% = 61.2 - 0.81*US.

Body condition score and live weight-

Body condition scores (Nicholson and Butterworth, 1986) were recorded each time the animals were weighed. Live weights were taken at the start of the experiment, then after two weeks during work and recovery periods and at the end of the experiment.

Rectal temperature, pulse (heart-beat) rate and respiration rate-

Rectal temperature, pulse (heart-beat) rate and respiration rate were recorded every two weeks during the work phase. In order to study the effect of work on heat load, rectal temperatures were measured using calibrated thermistors (RS Component, Corby, Northants, NN17 9RS, U.K.). The thermistors were connected to a data logger (21x Campbell Scientific, Utah, USA) for temperature readings. Respiration rate was measured by counting the number of flank movements (per 15 seconds). The rate of heartbeat was measured by placing a finger under the carotid artery and counting the number of beats per 15 seconds. The figures were then multiplied by 4 to give rate per minute. These records were taken at the following times into work on the working animal: 0, 2.5 and 5 h. The 2.5 h record was omitted in the case of non-working animals.

Pulling distance and speed-

The distance over which sledges were pulled was estimated by counting the number of rounds each animal covered at the work track. Each animal was guided along its tract during work by a technician who ensured that the animal worked continuously. Speed was measured at the following times into work: 0.0, 2.5 and 5.0 h, by measuring time each animal took to complete one round along the work track.

Laboratory analyses

Feeds were analyzed for DM, OM and N using standard procedures (AOAC, 1990).
Plasma urea was determined using the Berthelot UV-method (White *et al*., 1976).

Statistical analysis

The experiment was a completely randomized block design described by Snedecor and Cochran (1989). The general Linear Model (GLM) procedure (SAS, 1999) was used to test the effect of work and feeding level on body weight change during working and recovery periods. The statistical model used for the analyses of all variables was:

$Y_{ij} = \mu + B_i + T_j + Cov_j + E_{ij}$

Where: Y_{ij} = individual observations, μ = the overall mean, B_i = the block effect of body weights groups, T_j = the treatment effect, Cov_j = linear effect of initial live weight as covariate, E_{ij} = unexplained variation assumed normally and independently distributed.

When testing the effects of nutrient intake on compensatory responses, treatments T1 and T2 were excluded from the analysis. Non-orthogonal contrasts were used to compare treatment effects.

Results

Work phase

Effects of work and feed restriction on intake, and live weight change during the work phase-

During the work phase, all animals except those assigned to T1 lost weight (Table 2). Animals in T1 gained (378 g/d), while those within either the working or nutritionally restricted groups lost on average 106 g/d. Restricted feeding and work stress resulted in similar amounts of live weight loss (p>0.05). However, during working animals on restricted feeding lost less body weight than those fed *ad libitum* (41 vs. 106 g/day). Even though animals assigned to work were fed *ad libitum*, they had lower (p<0.001) DM and OM intakes than the control group (6.1 vs. 7.3 kg DM/d) while the work animals had higher DM and OM intakes (p<0.001) than the non-working and nutritionally restricted animals (6.1 vs. 4.0 kg DM/d) but the difference was not statistically significant (p>0.05).

Effect of work on rectal temperature (RT), pulse and respiration rates-

Within a day, work increased the rectal temperature (RT) significantly (p<0.001). At the beginning (0 h), all treatment groups had similar RT (37.0 ± 0.08°C). RT increased significantly as work progressed reaching values of 38.7 ± 0.08 °C and 39.1 ± 0.09 °C after 2.5 and 5h of work, respectively. Similarly, working animals had higher heartbeats (p<0.001) than non-working animals. As work progressed heartbeat increased from 44.4 ± 1.6 at 0 h to 61.6±2.8 and 66.4±2.9 after 2.5 and 5 h of work, respectively. Work also increased (P<0.001) the respiration rate, which was 23.7± 0.9 at 0 h then increased to 58.7± 4.5 and 64.5 ± 4.6 after 2.5 and 5 h of work, respectively.

Effect of work on speed-

Work performed by all work groups was similar and was done at similar speed (p>0.05). The number of rounds made per day was the same for all weight groups (143 ± 17.5 rounds per day which added to about 13.2 ± 2.1 km/d). Higher speed was observed at the beginning of work (0.70 ± 0.02 m/s); decreasing to 0.64 ± 0.02 m/s after 2.5 h which was maintained at this speed up to 5 h.

Recovery phase

Live-weight gain during the recovery phase-

During recovery feeding level, work had significant (p<0.001) effects on compensatory growth; restricted feeding induced faster (p<0.001) growth than *ad libitum* feeding (562 vs. 229 g/d) (Table 3). Animals on treatment 1 showed similar weight gains to those that received 0.7 times *ad libitum* during the recovery phase (229 vs. 226 g/d). There was no difference (P>0.05) between nutritionally restricted and working groups in ADG at the recovery phase at the same level of feeding. However, DMI and OMI were higher by 0.3 kg DM/d and OM/d for the work group (Table 3).

Fat depletion and repletion during the entire study-

The highest EBF ($p<0.001$) was observed at the end of the recovery period. However empty body fat was similar ($p>0.05$) among treatments during both the work and recovery phases of the trial (Figure 1).

Discussion

Effect of work and feed restriction during the work phase

The study revealed that non-working but nutritionally unrestricted (*ad libitum* fed) oxen had higher DMI than working oxen. This outcome confirmed the observation by Upadhyay (1987) that there was increased dry matter intake by non-working and *ad libitum* fed draught oxen. This finding may be also attributed to the differential rate of removal of feed residues from the rumen while the animals are at rest or restricted to exercise (Soller *et al*., 1986; Teleni and Hogan, 1989).

The depressed feed intake as a result of work stress in this trial is also in agreement with the results of Henning (1987), Tesfaye (1994) and Mathers *et al*., (1993) who indicated that working animals were unable to increase their appetite because work and associated activities may have left insufficient time for eating and rumination. The work stress also contribute to reduced feed intake by reducing the animal's desire to feed immediately after work because of decreased supply of nutrients to skeletal muscle to fuel feeding activity. The experiment also indicated that working animals with elevated body heat load of both metabolic and environmental origin have reduced appetite (Upadhyay, 1989; ARC, 1980).

Body weight gain of non-working and nutritionally unrestricted oxen was significantly higher when compared with that of the working and nutritionally stressed oxen. Konanta *et al,* (1986), Bamualim *et al.* (1987) and Tesfaye (1994) have reached to similar conclusion, and showed that live-weight gain of non-working animals were consistently higher than those of working animals, and that work and nutritional stress caused similar body weight losses. However, among the working animals, *ad libitum*-fed oxen consumed more DM than the nutritionally restricted group (Table 2). This could be due to the high demand for nutrients to support work, in addition to the low efficiency of energy utilization by the working animals (ARC, 1982). Lawrence *et al.* (1985) also indicated that there is high demand for nutrients because of higher metabolism of working animals whether at work or at rest.

Effect of work stress and feed restriction on rectal temperature and respiration and pulse rates-

A pull of 0.1 m/s has been considered optimum speed for work oxen (Takele *et al.,* 1989). This level of pull increased respiration and pulse rates and rectal temperature as work progressed without causing any adverse effects on the draught oxen. Maurya and Devendattan, (1982), Upadhyay (1987) and Takele *et al.* (1989) reported similar trends.

Effect of work stress and previous feed restriction on compensatory weight gain-

Both nutritional and work stressed animals showed higher body weight gain than the control during the recovery period. Additionally, animals stressed by either nutrition or work had similar body weight gain during the recovery period. Continuous and restricted feeding caused two differing rates of live-weight gain, in spite of identical levels of total feed offered (*ad libitum*) during the re-alimentation period. The lower live weight gain by the control group is due to a decreased efficiency of energy utilization when the level of feeding is increased for a prolonged period (more than 90 days) (ARC, 1980). An interesting observation was that despite the lighter body weight of oxen in T2 (no work, restricted feeding) during the recovery period, they had the highest average daily gain (562 g/day). Thus, at similar intakes for non-working animals, more energy will be available for growth (Wright and Russel, 1991). Cattle on restricted feeding had more efficient feed conversion efficiency than those on *ad libitum* feeding (Anderson, 1975).

Compositional changes during work and recovery phases-

A greater increase in protein than fat deposition during compensatory growth in cattle has been reported (Butterfield *et al*., 1971). The repletion of fat may occur after the deposition of protein during the course of compensatory growth. Change in empty body fat during the working phase was observed, but there was no difference between working and non-working oxen. The exact period at which fat is mobilized and deposited in the adipose tissue of cattle after prolonged re-alimentation is not well understood. The estimate of changes in body fat composition during the 51 days working period indicated that fat reserves were depleted in all animals while fat was deposited during the recovery period. Fat depots were being utilized as energy sources and this helps to explain the apparent inefficiencies in the utilization of dietary energy (ARC, 1980). The result is in agreement with that of Tesfaye (1994) who observed that long chain fatty acids were mobilized from adipose tissue to fuel work activity. The similarity of empty body fat (EBF) among treatments was in agreement with the results reported by Rompala *et al.* (1985) and Drouillard *et al*. (1991) who showed no differences in body composition between re-alimented and normally grown animals. It was observed that EBF deposition reduced ($p<0.05$) during the working period. There was no increment in EBF during mid recovery but it increased towards the end of the recovery period ($p<0.001$). This result is in agreement with that of Winter *et al.* (1976) and Carstens *et al*. 1989 who showed that compensatory growth, especially one which occurred soon after re-alimentation was due mainly to an increase in non-carcass components (changes in the digestive tract). This may be due to extra water in the gut increased appetite and the associated gut fill effects (Drew and Reid, 1975). Also accumulation of lean tissue during the early re-alimentation period could reduce the proportion of EBF (Meissner *et al*., 1977).

Conclusion

This experiment revealed that work depressed intake by a proportion of 16% (7.3 to 6.1 DM kg /day). The loss in body weight due to work and nutritional stress could be recovered within 84 to 90 days of feeding good quality feed equivalent to 13 - 14 MJ per kg DM. Compensatory gain improves feed utilization, suggesting that it is economical to feed animals below maintenance and feed them *ad libitum* in preparation for market or slaughter. The nutrient requirement for optimum compensatory growth following an intermediate level of work (100 g/kg LWT) with good quality feed during recovery phase is

0.9 times *ad libitum* feeding. This is about 21.1 g DOMI per kg live-weight or 1.6 times maintenance energy requirement.

Draught oxen perform effective work if fed up to 0.8 times maintenance of energy requirement. Energy deficit caused by work or nutritional stress was compensated by the same quantity of *ad libitum* feeding at the re-alimentation period. It is also advisable to fatten working oxen immediately after the last working season to take advantage of compensatory growth.

Table 2. Effect of treatment on dry matter intake (DMI), organic matter intake (OMI) and average daily gain (ADG) during the working period.

Treatment	**N**	**Initial**	**DMI**	**OMI**	**DML**	**ADG**	**DOMI**
1	5	298	7.3	6.6	23.9	378	6.7
2	4	282	4.0	3.8	13.6	-41	4.6
3	5	293	5.7	5.1	19.8	-175	4.9
4	5	292	5.9	5.3	20.3	-118	5.0
5	4	308	6.3	5.6	21.2	-76	5.3
6	5	295	6.3	5.6	20.9	-56	5.0
SED		14.3	0.18	0.16	0.60	58	0.18
Contrast							
T_1 vs. T_2			***	***	***	***	***
T_1 vs. T_{3-6}			***	***	***	***	***
T_2 vs. T_{3-6}			***	***	***	NS	*

SEM-Standard error of mean, *= p<0.05, **= p<0.01, ***= p< 0.001 and NS= Not Significant (p>0.05),

(N)= number of animals, MI =Dry Matter Intake kg/d, DML =Dry Matter Intake g per kg Live Weight, DOMI= Digestible Organic Matter Intake kg/d,

Table 3. Effect of treatment on feed intake, organic matter intake and average daily gain (ADG) during the recovery period.

Treatment	**N**	**DMI**	**OMI**	**DML**	**ADG**	**DOMI**	**Final Body Weight**
1	5	6.6	6.1	22.0	229	6.5	313
2	4	6.7	6.2	22.0	562	7.1	342
3	5	5.0	4.6	17.0	226	4.8	315
4	5	5.8	5.3	19.0	366	5.6	325
5	4	6.4	5.9	21.3	435	6.3	332
6	5	7.0	6.5	22.8	458	7.6	330
SEM		0.16	0.14	0.45	68.5	0.22	4.828
Contrast							
T_1 vs. T_2		NS	NS	NS	***	*	***
T1 vs. T3		***	***	***	NS	***	NS
T_2 vs. T_6		NS	**	NS	NS	NS	NS

SEM-Standard error of mean, *= p<0.05, **= p<0.01, ***= p< 0.001 and NS= Not Significant (p>0.05),

(N)= number of animals, MI =Dry Matter Intake kg/d, DML =Dry Matter Intake g per kg Live Weight, DOMI= Digestible Organic Matter Intake kg/d,

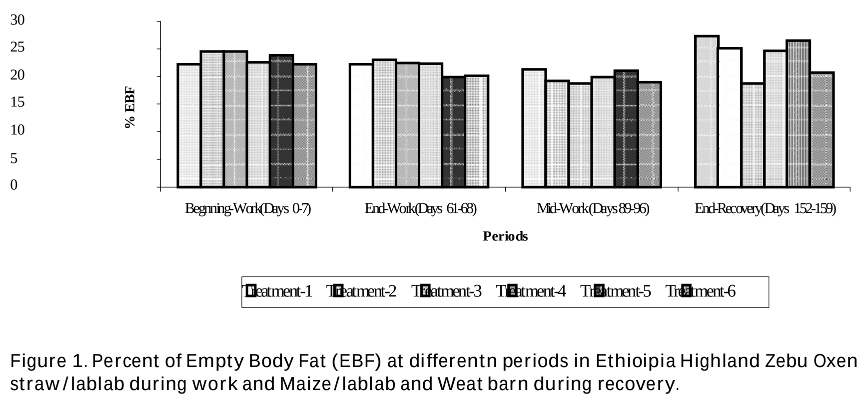

Figure 1. Percent of Empty Body Fat (EBF) at differentn periods in Ethioipia Highland Zebu Oxen fed teff straw/lablab during work and Maize/lablab and Weat barn during recovery.

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