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Effect of work conditions on oxygen uptake and energy cost of test draught he-buffalo

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ABSTRACT

Test draught he-buffalo was used on the animal treadmill at different work conditions under a controlled environment for a period of four hours or upto the test draught he-buffalo reached a state of fatigue for determining oxygen uptake and energy cost. Oxygen uptake and energy cost result showed regular increasing trend at all speeds, inclination of treadmill, draughts and combination of temperature and humidity. Oxygen uptake requirement and variation in energy cost at 42^{0}C temperature was higher as compared to 22^{0}C temperature, and it increases with increase in humidity. The increment in maximum oxygen uptake was observed as 669.124% (2.0 km/h speed, 5^0 inclination of treadmill, 14% draught and 42^{0}C temperature with 90% humidity). Oxygen uptake changes with changes in respiration rates, tidal volumes, oxygen extraction percentage, humidity levels and high ambient temperature. Increase in oxygen uptake was found to be more sensitive to draughts so it can be used as an indicator of stress. Oxygen uptake and energy costs model showed good correlation with independent variables and there R^2 value was in the acceptable range. This model can be used in oxygen requirement and energy cost estimation in the out-field experiment for efficient utilization of muscle power of test draught he-buffalo.

Key Words : Speed, Inclination of treadmill, Draught, Temperature, and Humidity

INTRODUCTION

Animal traction has a long history in agricultural production. It is an appropriate, affordable and sustainable technology requiring very low external inputs. Draft animals not only reduce drudgery and intensify agricultural production but also raise living standards of rural community. The draught animal power is still one of the major sources of farm power in the world. Sub-Saharan Africa and South-Eastern Asia are two regions of the world where draught animals are an important source of power for farm activities. In South-East Asia, buffalo and cattle are dominant sources of power in the low land rice and the upland intensive mixed farming systems (FAO, 2001) where they are used mainly for primary tillage with limited use in secondary operations such as planting and weeding. Draught animal power is also important in the rice and rainfed farming systems of South Asia (FAO, 2001), and in the mountainous area of South Asia where the terrain is not suitable for tractors. Draught animals provide an important source of power in agriculture in India and would continue to fulfill this vital role for many more decades. Increased intensity of cropping demands and increased energy inputs in agriculture puts pressure on the other sources of energy like petroleum oil, electricity, and coal etc., which are scarce and costly. Therefore, efforts are underway to increase the use and overall efficiency of draught animals to reduce pressure on other sources of energy. Introduction of animal traction depends upon a thorough study and understanding of the animal husbandry, farming systems and Pedi-climatic conditions for the development of appropriate animal-drawn equipment. He-buffalo is the classic work animal because of some of the positive characteristics such as efficient utilization of low-quality roughages and water plants, less selective grazers, little or no problem with ticks, maintain good body conditions during the dry and hot summer season and work well in a flooded paddy field. The buffalo is recognized as an efficient working animal in situations where speed is unimportant. However, buffaloes appear to be inferior to cattle on hard surfaces due to their slower rate of walking, which is said to average 3.2 km/h, and a lower degree of heat tolerance (Since buffaloes have lower number of sweat glands from 1.83 to 4.32 per mm^2 of skin as compared to bullocks which have 13 to 16 per mm^2 of skin). The important factors which affect the output of buffaloes are breed, size, weight, method of hitching, training for work, quality of feed and the state of health.

The draught buffaloes are in continuous stress during tillage operations especially in summer season, extreme winter and rainy seasons. The thermoregulatory system of buffalo has to adjust its body failing which it is in fatigue under excessive environmental and draught loads. The success of the utilization of draught animal power depends upon the scientific investigation undertaken to optimize animal power utilization. The determination of work output of buffalo during sustained working without undue fatigue is important. The information on oxygen uptake and energy cost of draught buffalo while performing the work in the field on varying speed, draught and field slopes in different seasons are lacking at present. Considering the lack of study related with the effect of work conditions on oxygen uptake and energy cost of test draught he buffalo during treadmill exercise under controlled environment was performed for

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better utilization of muscle power of the draught he-buffalo. Agarwal and Upadhyay (1997) studied the oxygen uptake with Murrah buffaloes with a mean body weight of 220 ± 5 kg. Animals were exercised on an animal treadmill for one hour at 5 km/h speed when ambient conditions were hot humid (temperature 32.5 to 34.4°C and humidity 72 to 75%). A mean increase in the volume of oxygen uptake by 22.65% was observed. Ribeiro *et al.*(1977) studied the energy cost of walking on the treadmill of four weaned and castrated young male cattle (British Friesian). They observed that mean values of energy cost of horizontal walking (H_h) were 1.92 J/kg/m at 40.3 m/min (2.42 km/h) and 2.36 J/kg/m at 80.6 m/min (4.84 km/h) and mean values of energy cost at 6° gradient walking (H_g) were 5.16 J/kg/m at 40.3 m/min (2.42 km/h) and 4.56 J/kg/m at 80.6 m/min (4.84 km/h), whereas calculated mean values of energy cost of vertical ascent ($H_h - H_g$ / sin6°) were 31.0 J/kg/m at 40.3 m/min (2.42 km/h) and 20.0 J/kg/m at 80.6 m/min (4.84 km/h). They concluded that, the energy cost of horizontal walking (H_h) was less than that of 6° gradient walking (H_g) and of vertical ascent ($H_h - H_g$ /sin6°). Gupta and Rao (1990) studied the effect of different speeds and gradients upon the energetic efficiency of work in six normal and healthy crossbred bullocks. An increase in oxygen uptake by 47% at 5 km/h speed and at 20° gradients compared to 2 km/h speed from its resting level was observed. The energy output decreased with increase in gradients during both the speeds whereas, energy output increased with increase in speeds. During this investigation, gross energetic efficiency increased with increase in speeds and also increased with gradients, but the increase in gross energetic efficiency was not uniform with increase in gradients. At gradients of 10º and 15° slight decreases in gross energetic efficiency with speed of 2 km/h was observed.

Whereas at the same speed gross energetic efficiency was higher when the gradient was increased to 20°. Similarly, there was an increase in gross energetic efficiency when the gradient was raised to 10° from the horizontal level (0° gradient) with 5 km/h speed. However, gross energetic efficiency was observed to be less at the gradients 15°and 20° at 5 km/h speed. They concluded that oxygen uptake increased with increase in speed and gradients which supplied sufficient oxygen to tissue at work. Upadhyay and Aggarwal (1997) studied the oxygen uptake due to sweating of six apparently healthy male calves. Animals were exercised on a treadmill for one hour at 5 km/h speed when ambient conditions were hot dry (temperature 35 to 38ºC and humidity, 59 to 62.5 %). A significant increase in volume of oxygen uptake by 39.72% from its resting level was observed. Thomas and Fregin (1981) conducted a study on cardio-respiratory and metabolic responses to treadmill exercise on horses. They concluded that oxygen uptake (Vo_2) increased from 1.1 ± 0.1 to 32.7 ± 2.1 lit/min and respiratory exchange ratio (RQ) increased from 0.83 ± 0.02 to 0.96 ± 0.01. In addition, three of the horses were willing to trotted at a sixth stage (14 km/h, 11.5% gradient), which elicited a Vo_2 of 39.8 ± 0.3 lit/min and on respiratory exchange ratio (RQ) of 0.98 ± 0.01. Art and Lekeux (1993) studied the effects of training and detraining on metabolic measurements. They concluded that training induced a significant increase in Vo_2 peak, therefore three weeks of training was suggested which was sufficient to induce significant physiological changes as long as the intensity of the training was high. Davie *et al.* (1999) studied the effect of muscle glycogen depletion on some metabolic and physiological responses to sub-maximal treadmill exercise of Thoroughbred Geldings. It was concluded that oxygen uptake does not significantly affected during moderate exercise. Marlin *et al.*(1999) studied physiological responses of horses to a treadmill simulated speed and endurance test in high heat and humidity before and after humid heat acclimation of healthy horses. They observed that, maximal oxygen uptake was not changed following acclimation (pre-acclimation 141 ± 8 ml/min per kg body weight vs. post acclimation 145 ± 9 ml/min per kg body weight). McDonough *et al.* (2002) studied the effect of treadmill inclination on maximal oxygen uptake of Thoroughbred horses exercised on a treadmill. They reported that, maximal oxygen uptake at 10% gradient was 77.81 lit/min and at level zero percent was 65.51 lit/min. They concluded that maximal oxygen uptake was always higher during inclined treadmill than level running. The review of past research indicates that a good amount of work has been done on various aspect of draught animal power and emphasis has been given on suitable work-rest schedule for bovine animals for increasing their efficiency by increasing their draught-ability. The above review reveals that in addition to draught, the environmental factors mainly the ambient temperature has pronounced effect on the oxygen uptake and energy cost. However, the research works on the effect of work conditions on oxygen uptake and energy cost of test draught he buffalo during treadmill exercise under controlled environment is almost negligible. Therefore, effort has been made to determine the effect of work conditions on oxygen uptake and energy cost of test draught he buffalo during treadmill exercise under controlled environment during winter and summer season at a safe load equivalent to 0 and 14% body weight of he-buffaloes and at variable speeds between 1.5 and 2.0 km/h.

MATERIALS AND METHODS

Prior to the start of the experiment the required level of temperature and humidity were maintained in the environmental controlled chamber. The environment controlled chamber is an air tight room in which temperature and humidity are controlled independent of each other and kept constant within minimum differences at any particular level. The effects of one or two climatic factors or their combinations were studied on oxygen uptake of the test draught he-buffalo with different level of workloads.

The test draught he-buffalo was allowed to climb on the animal treadmill followed by harnessing with the help harness and another harness was connected to the hanging weight type loading device with U-shape piped frame where loads could be placed. Loads equivalent to 0 and 14% body weight of test draught he-buffalo were kept in a hanging pan hanged through a rope and pulley arrangement. The treadmill was calibrated before starting the experiment. The experiment was carried out in 22^{0}C and 42^{0}C temperature and 45% and 90%humidity combinations during the whole of the experiment. The he-buffalo was exercised on a treadmill at two draughts, two speeds and three inclinations of the treadmill for a period of four hours or upto the test draught he-buffalo reached a state of fatigue. The oxygen uptake was recorded before starting and just after completion of the exercise on a treadmill.

Measurement of Oxygen uptake during treadmill exercise of test draught he-buffalo

Oxygen uptake is the volume of oxygen consumed per min. by an organism. To determine the oxygen uptake Bendit Roth Spirometer was used. Spirometer is an instrument used to measure respired volumes and oxygen uptake with closed circuitary. Bendit Roth Spirometer mainly consists of mouth piece which is fixed with the mouth of the test draught he buffalo, rubber hose of 25 mm internal diameter, three-way valve for regulating flow of respired air to spirometer, thermometer for measuring temperature of respired air, bell for collection of pure oxygen, counter weight attached with bell for balancing oxygen level, base, recording drum on which recording chart is fixed, with four speeds viz. 0, 2, 0.4 and 20 mm/sec and a pointer attached with counter weight which marks on the chart paper.

To measure the oxygen uptake of test draught he buffalo mouth piece of the spirometer was attached to the mouth of the test draught he buffalo after that the spirometer was kept in working condition. The test draught he buffalo starts breathing through mouth piece and consumes oxygen filled in the bell. The level of the bell lower down as draught he buffalo inspired and the pointer attached with bell records the volume of oxygen uptake by the test draught he buffalo on chart/graph. The graph obtained through the above instrument is known as kymograph and it is analyzed for oxygen uptake (l/min.).

Measurement of Energy cost during treadmill exercise of test draught he-buffalo

The energy cost of the working test draught he-buffaloes was calculated by multiplying the volume of oxygen uptake (l/min) by the test draught he-buffaloes during exercise on treadmill under controlled environmental conditions with a value of 20.192 kJ/l (or 4.825 Cal/l) as suggested by Broody (1945).

RESULTS AND DISCUSSION

The oxygen uptake of test draught he-buffaloes on the animal treadmill was evaluated for determining their work efficiency without undue fatigue. Two he-buffaloes were exercised on a treadmill at two levels of speeds, temperature and humidity, three inclinations of treadmill and two levels of draughts for a period of four hours or time till draught he-buffalo reached a state of fatigue under different workloads. The variation in oxygen uptake of test draught he-buffaloes during exercise on animal treadmill under controlled environmental conditions (Table 1). During the study, the effect of higher humidity was found significant for oxygen uptake and energy cost.

Variation in Oxygen uptake of test draught he-buffaloes

The minimum and maximum oxygen uptake of test draught he-buffaloes at 1.5 km/h speed, 22^{0}C temperature and 45% humidity and 0^0 inclination of treadmill, increased from resting level by 13.78 and 41.24% for 0 (No load) and 14% draught, respectively after 4 hours of treadmill exercise (Table 1). At 5^0 inclination of treadmill, the minimum and maximum oxygen uptake of test draught he-buffaloes increased from its resting level by 124.40 and 373.06% for 0 (No load) and 14% draught, respectively after 4 hours of treadmill exercise whereas at 10^0 inclination of treadmill, the increase in oxygen uptake (minimum and maximum) was found as 128.63 and 384.69% for 0 (No load) and 14% draught, respectively after 4 hours of treadmill exercise. Other conditions remaining similar but at 90% humidity, the minimum and maximum oxygen uptake at 0^0 inclination of treadmill increased from its resting level by 30.41 and 91.11% for 0 (No load) and 14% draught, respectively after 4 hours of exercise. At 5^0 inclination of treadmill, the corresponding increase in oxygen uptake (minimum and maximum) was found as 141.03 and 422.94% for 0 (No load) and 14% draught, respectively after 4 hours of exercise on treadmill while minimum and maximum oxygen uptake increased from its resting level by 147.25 and 441.63% for 0 (No load) 14% draught, respectively after 4 hours exercise on treadmill for 10^0 inclination.

The minimum and maximum oxygen uptake of test draught he-buffaloes at 2.0 km/h speed, 22^{0}C temperature and 45% humidity of controlled chamber at 0^0 inclination of treadmill increased from its resting level by 54.75% and 309.55% for 0 and 14% draught, respectively after 4 hours of exercise. At 5^0 inclination of treadmill, the minimum and maximum oxygen uptake of test draught he-buffaloes increased from its resting level by 291.78% and 379.48% for 0 and 14% draught, respectively after 4 hours of exercise while it increased (minimum and maximum) from its resting level by 326.44% for 0% draught after 4 hours of exercise and 460.51% for 14% draught after 1 hour of exercise on treadmill at 10^0 inclination. From the same table it is also clear that at 2.0 km/h speed with 0 and 10^0 inclination of treadmill and different levels of draught at 22^{0}C temperature and 90% humidity, the minimum and maximum oxygen uptake of test draught he-buffaloes increased from its resting level by 81.52, 349.70% for 0% (No load) and 14% draught, respectively after 4 hours of exercise. At 5^0 inclination of treadmill, the respective increase in minimum and maximum oxygen uptake of test draught he-buffaloes was recorded as 315.72 and 526.16% for 0 (No load) and 14% draught, respectively after 4 hours of exercise while it minimum and maximum oxygen uptake increased from its resting level by 364.94% for 0% draught after 4 hours of exercise and 608.20% for 14% draught after 1 hour of exercise at 10^0 inclination of treadmill.

It was observed that oxygen uptake of test draught he-buffaloes at 1.5 km/h speed with 0^0 inclination of treadmill and different levels of draught at 42^{0}C temperature and 45% humidity increased from its resting level by 58.53 for 0% (No load) draught after 4 hours of exercise and 175.46% for 14% draught after 2 hours of exercise while at 5^0 inclination of

Speed, km/h	Inclination of treadmill, degree	Draught, (% of body weight)*		Temperature, °C = 22									
				Humidity, % = 45					Humidity, % = 90				
				Duration of exercise, h					Duration of exercise, h				
				0 (IN)	1	2	3	4	0 (IN)	1	2	3	4
1.5	0	0	Average	8.97				10.20	8.97				11.69
			P.C.					**13.78**					**30.41**
		14	Average	8.97				12.66	8.97				17.13
			P.C.					**41.24**					**91.11**
	5	0	Average	8.97				20.12	8.97				21.61
			P.C.					**124.40**					**141.03**
		14	Average	8.97				42.41	8.97				46.88
			P.C.					**373.06**					**422.93**
	10	0	Average	8.97				20.46	8.97				22.17
			P.C.					**128.27**					**147.25**
		14	Average	8.97				43.45	8.97				48.56
			P.C.					**384.69**					**441.63**
2.0	0	0	Average	8.97				13.87	8.97				16.27
			P.C.					**54.75**					**81.52**
		14	Average	8.97				36.72	8.97				40.32
			P.C.					**309.55**					**349.70**
	5	0	Average	8.97				35.12	8.97				37.27
			P.C.					**291.78**					**315.72**
		14	Average	8.97				42.99	8.97				56.14
			P.C.					**379.48**					**526.16**
	10	0	Average	8.97				38.23	8.97				41.68
			P.C.					**326.44**					**364.94**
		14	Average	8.97	50.25	#			8.97	63.49	#		
			P.C.		**460.49**					**608.20**			
				Temperature, °C = 42									
1.5	0	0	Average	8.97				14.21	8.97				29.36
			P.C.					**58.53**					**227.49**
		14	Average	8.97		24.70	#		8.97		50.36	#	
			P.C.			**175.46**					**461.70**		
	5	0	Average	8.97				25.59	8.97				40.74
			P.C.					**185.42**					**354.38**
		14	Average	8.97		47.88	#		8.97		63.03	#	
			P.C.			**434.09**					**603.05**		
2.0	0	0	Average	8.97				19.34	8.97				32.68
			P.C.					**115.77**					**264.53**
		14	Average	8.97		40.09	#		8.97		52.36	#	
			P.C.			**347.22**					**484.00**		
	5	0	Average	8.97				35.29	8.97				42.00
			P.C.					**293.65**					**368.49**
		14	Average	8.97	62.87	#			8.97		68.95	#	
			P.C.		**601.32**						**669.12**		

P.C. = Percentage change
*Body weight of 1st buffalo = 434 kg
Body weight of 2nd buffalo = 444 kg
=Test draught he-buffalo did not exercise due to fatigue

treadmill, the corresponding increase in oxygen uptake was recorded as 185.42% for 0% draught after 4 hours of exercise and 434.09% for 14% draught respectively after 2 hours of exercise on treadmill (Table 1).

Other conditions remaining similar but at 90% humidity the oxygen uptake at 0^0 inclination of treadmill increased from its resting level by 227.49% for 0% draught after 4 hours of exercise and 461.70% for 14% draught after 2 hours of exercise on treadmill, whereas the corresponding increase in oxygen uptake was recorded as 354.38% for 0% draught after 4 hours of exercise and 603.05% for 14% draught after 2 hours of exercise on treadmill at 5^0 inclination.

The oxygen uptake of test of draught he-buffaloes at 2.0 km/h speed,42^0C temperature, and 45% humidity of controlled chamber. Result showed that at 0^0 inclination of treadmill, the oxygen uptake of test draught he-buffaloes increased from its resting level by 115.77% for 0% draught after 4 hours of exercise and 347.22% for 14% draught after 2 hours of exercise whereas the respective increase in oxygen uptake was recorded as 293.65% for 0% draught after 4 hours of exercise and 601.32% for 14% draught after 1 hour of exercise on treadmill at 5^0 inclination while at 90% humidity the oxygen uptake of test draught he-buffaloes increased from its resting level by 264.53% for 0% draught after 4 hours of exercise and 484.00% for 14% draught after 3 hours of exercise at 0^0 inclination but it increased as 368.49% for 0% draught after 4 hours of exercise and 669.12% for 14% draught after 2 hours of exercise on treadmill at 5^0 inclination (Table 1).

The rate of oxygen uptake of test draught he-buffaloes increases with increase in draught at all combinations of temperature, humidity, speeds, and inclinations. The requirement of oxygen uptake during 42^0C temperature was higher in comparison to 22^0C temperature. When the humidity level increases the requirement of oxygen also increases to compensate the requirement of energy for exercise on treadmill (Table 1). Increment in maximum oxygen uptake observed in the present study as 669.124% (2.0 km/h speed, 5^0 inclination of treadmill, 14% draught and 42^0C temperature with 90% humidity) was comparatively much lower in he buffalo as compared to reports on trained horses where 18.24 times increased oxygen uptake has been reported (Swenson and Recee, 1993). The rise in oxygen uptake paralleled the rise in speed, inclination of treadmill, draught, environmental temperature and humidity. Amount of exercise had a direct implication on oxygen uptake and is directly related with metabolic and energy demand of muscles. Oxygen uptake changes with changes in respiration rates, tidal volumes, oxygen extraction percentage, humidity levels and high ambient temperature resulted in more oxygen uptake due to distress caused by heat load conditions. The above increase in oxygen uptake was in agreement with the findings of Aggarwal and Upadhyay (1998) who reported an increase in oxygen uptake to 0.71 l/min in buffalo during exposure in solar radiation. Upadhyay and Aggarwal (1997) also reported 39.72% increase in oxygen uptake after treadmill exercise in bullocks.

Analysis of Variance revealed that all the parameters and their interactions have significant effect except (speed × inclination of treadmill × draught) on oxygen uptake at 1% level of probability at both the levels of temperature (Table 2).

Table 2 : Analysis of Variance for oxygen uptake, (l/min.) of test draught he-buffalo exercised on an animal treadmill under a controlled environment at different work loads

Parameters	d.f.	S.S.	M.S.S	f -value	Significantce	SEm (±)	CD (5%)
			Temperature, ^{0}C = 22				
i	1.	2855.8	2596.2	22530.14	**	.56E-01	.682
j	2.	6532.7	3110.8	26995.88	**	.69E-01	.755
k	2.	3759.2	1790.1	15534.57	**	.69E-01	.755
l	1.	399.0	362.7	3147.927	**	.56E-01	.682
ij	2.	64.2	30.5	265.3901	**	.97E-01	.897
ik	2.	4.2	2.0	17.59786	**	.97E-01	.897
il	1.	45.2	41.	357.2262	**	.80E-01	.811
jk	4.	112.0	27.3	237.1285	**	.12079	.993
jl	2.	30.8	14.6	127.4440	**	.97E-01	.897
kl	2.	81.9	39.0	338.6886	**	.97E-01	.897
ijk	4.	554.7	135.3	1174.235	**	.169	1.18
ijl	2.	25.4	12.1	105.0291	**	.138	1.06
ikl	2.	13.3	6.3	55.01263	**	.138	1.06
jkl	4.	14.9	3.6	31.65660	**	.169	1.18
ijkl	4.	13.9	3.3	29.42952	**	.240	1.40
Error	36.	4.14	.1149152				
Total	71.	14512.05	204.1076				
C.V.	1.0291970						

Temperature, ⁰C = 42							
i	1.	629.1614	571.9649	4949.511	**	.6939017E-01	.7688653
j	1.	2475.635	2250.578	19475.42	**	.6939017E-01	.7688653
k	2.	3685.016	1754.769	15184.93	**	.8498526E-01	.8508893
l	1.	2603.526	2366.842	20481.52	**	.6939017E-01	.7688653
ij	1.	7.343750	6.676136	57.77208	**	.9813252E-01	.9143401
ik	2.	44.64325	21.25869	183.9625	**	.1201873	1.011884
il	1.	203.4635	184.9668	1600.614	**	.9813252E-01	.9143401
jk	2.	118.7083	56.52774	489.1640	**	.1201873	1.011884
jl	1.	193.1092	175.5538	1519.159	**	.9813252E-01	.9143401
kl	2.	35.83325	17.06345	147.6590	**	.1201873	1.011884
ijk	2.	.1484375	.7068453E-01	.6116700	ns	.1699705	1.203339
ijl	1.	1.166809	1.060735	9.179097	**	.1387803	1.087340
ikl	2.	18.67714	8.893876	76.96334	**	.1699705	1.203339
jkl	2.	41.51579	19.76943	171.0751	**	.1699705	1.203339
ijkl	2.	14.99707	7.141462	61.79879	**	.2403746	1.431020
Error	24.	2.773438	.1150804				
Total	47.	10075.72	213.9218				
C.V.	.8215460						

** = Significant at 1% level of probability
* = Significant at 5% level of probability
ns = Non significant statistically
i = Speed, km/h
j = Inclination of treadmill, degree
k = Draught, (% of body weight)
l = Combination of temperature and humidity
C.V. = Coefficient of variation

Model for oxygen uptake was developed using multiple linear regression analysis. Regression analysis for oxygen uptake shows that humidity, temperature, speed, inclination of treadmill and draught has significant effect. The overall R^2 value for developed model for oxygen uptake was found as 0.8473. The contribution in total R^2 value for developed model was higher for draught (0.2630) and minimum for humidity (0.0763). Developed model for oxygen uptake is represented in equation (1)

Oxygen uptake, l/min = - 54.3860 + 0.1937 (H) + 0.7077 (T) + 20.9079 (S) + 2.3037 (I) + 1.2971 (D) .... (1)

Where,

H = Humidity, %
T = Temperature, ⁰C
S = Speed, km/h
I = Inclination of treadmill, deg.
D = Draught, percentage of body weight

Variation in the energy cost of test draught he-buffaloes

To measure the variation in the energy cost of test draught he buffaloes, the volume of oxygen uptake (l/min) by the test draught he-buffaloes during exercise on treadmill under controlled environmental conditions was multiplied with a value of 20.192 kJ/l (4.825 Cal/l) as suggested by Broody (1945). The variation in the energy cost of test draught he-buffaloes during exercise on treadmill under controlled environmental conditions at three inclinations of treadmill and two level of draught, two levels of speed, temperature and humidity. There is a similar increasing trend as in case of oxygen uptake in energy cost of test draught he-buffaloes from its resting level at all speeds, inclinations, draughts, temperatures and humidity combinations. The requirement of energy cost during 42⁰C temperature was higher in comparison to 22⁰C temperature (Table 3).

Model for energy cost was developed using multiple linear regression analysis. After regression analysis is was found that humidity, temperature, speed, inclination of treadmill and draught has significant effect on energy cost. The overall R^2 value for developed model for energy cost was found as 0.8473. The contribution in total R^2 value for developed model was higher for draught (0.2630) and minimum for temperature (0.0763). Developed model for energy cost is presented in equation (2)

Energy cost, Cal/min = - 262.4122 + 0.9346 (H) + 3.4147 (T) + 100.8806 (S) + 11.1154 (I) + 6.2585 (D) ....(2)

Where,

H = Humidity (%)
T = Temperature (⁰C)
S = Speed (km/h)
I = Inclination of treadmill (degree).
D = Draught, percentage of body weight

CONCLUSION

Draught animal power constitutes a very high proportion of renewable energy source in agriculture. This is easily available and can be harnessed efficiently. Its techno-economic feasibility and viability are well within the reach of the small and marginal farmers. Most of the draught work

at different work loads

Speed, km/h	Inclination of treadmill, degree	Draught, (% of body weight)*		Temperature, ^0C = 22									
				Humidity, % = 45					Humidity, % = 90				
				Duration of exercise, h					Duration of exercise, h				
				0 (IN)	1	2	3	4	0 (IN)	1	2	3	4
1.5	0	0	Average	43.28				49.22	43.28				56.41
			P.C.					**13.71**					**30.33**
		14	Average	43.28				61.09	43.28				82.67
			P.C.					**41.16**					**91.00**
	5	0	Average	43.28				97.07	43.28				104.26
			P.C.					**124.27**					**140.89**
		14	Average	43.28				204.63	43.28				226.20
			P.C.					**372.80**					**422.64**
	10	0	Average	43.28				98.74	43.28				106.95
			P.C.					**128.14**					**147.11**
		14	Average	43.28				209.66	43.28				234.29
			P.C.					**384.42**					**441.33**
2.0	0	0	Average	43.28				66.94	43.28				78.52
			P.C.					**54.66**					**81.42**
		14	Average	43.28				177.16	43.28				194.53
			P.C.					**309.32**					**349.45**
	5	0	Average	43.28				169.47	43.28				179.82
			P.C.					**291.56**					**315.49**
		14	Average	43.28				207.40	43.28				270.85
			P.C.					**379.21**					**525.81**
	10	0	Average	43.28				184.46	43.28				201.12
			P.C.					**326.20**					**364.68**
		14	Average	43.28	242.45	#			43.28	306.34	#		
			P.C.		**460.18**					**607.80**			
				Temperature, ^0C = 42									
1.5	0	0	Average	43.28				68.57	43.28				141.66
			P.C.					**58.44**					**227.30**
		14	Average	43.28		119.15	#		43.28		242.97	#	
			P.C.			**175.31**					**461.38**		
	5	0	Average	43.28				123.46	43.28				196.55
			P.C.					**185.26**					**354.13**
		14	Average	43.28		231.03	#		43.28		304.11	#	
			P.C.			**433.79**					**602.65**		
2.0	0	0	Average	43.28				93.34	43.28				157.68
			P.C.					**115.65**					**264.33**
		14	Average	43.28		193.45	#		43.28		252.62	#	
			P.C.			**346.97**					**483.68**		
	5	0	Average	43.28				170.28	43.28				202.65
			P.C.					**293.43**					**368.23**
		14	Average	43.28	303.36	#			43.28		332.69	#	
			P.C.		**600.93**						**668.70**		

P.C. = Percentage change
*Body weight of 1st buffalo = 434 kg
Body weight of 2nd buffalo = 444 kg
=Test draught he-buffalo did not exercise due to fatigue

from bovine, which are major draught animals in India, is in terms of tillage and carting. The oxygen uptake plays an important role in the determination of energy cost for efficient utilization of muscle power of draught animals. On the basis of experimental results obtained under the study following conclusions were drawn:

- Oxygen uptake and energy cost showed the regular increasing trend at all speeds, inclination of treadmill, draughts and combination of temperature and humidity. Oxygen uptake requirement during 42^0C temperature was found to be higher compared to 22^0C temperature and increases with increase in humidity.
- Increment in maximum oxygen uptake was observed at 2.0 km/h speed, 5^0 inclination of treadmill, 14% draught and 42^0C temperature with 90% humidity.
- Duration of exercise showed direct implication on oxygen uptake and was directly related with metabolic and energy demand of muscles.
- Variation in energy cost showed similar increasing trend as in case of oxygen uptake with higher energy cost at 42^0C temperature compared to 22^0C temperature.
- Increase in oxygen uptake was found to be more sensitive to draughts so it can be used as an indicator of stress.

Models developed for oxygen uptake and energy costs showed good correlation with independent variables and can be used for determining oxygen requirement and energy cost without performing experiment in the field for efficient utilization of muscle power of test draught he-buffalo.

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