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Work Potential and Physiological Responses of Donkeys at Different Sets of Pressures During Water Lifting at Constant Suction Head

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Abstract: A sttudy was conducted using two pairs of donkeys to lift water from 3m suction head. Three discharge pressure heads (1.0, 1.5 and 2.0 kg/cm^2.) were created using a 38 mm x 32 mm reciprocating pump. The donkeys worked for 5 hrs, 4 hrs and 3 hrs respectively at the above pressure heads before they were fatigued. The pump discharged 5056.66 ± 58.11 to 4316.66 ± 60.90, 4953.33 ± 37.11 to 4036.66 ± 44.09 and 4726.66 ± 53.64 to 4066.66 ± 88.19 liters of water per hour at the corresponding pressures. The corresponding power developed by the animals, to obtain the above discharge was 0.72 ± 0.01 to 0.49 ± 0.01, 0.78 ± 0.02 to 0.45 ± 0.06 and 0.83 ± 0.02 to 0.56 ± 0.04 kW respectively. The walking speed of the donkeys, power developed and water discharged showed a decreasing trend over the duration of work. Calculations showed that pressure of 1.5 and 2.0 kg/cm^2 was suitable for drip irrigation for appropriate widely spaced horticultural crops on a small scale. The pulse rate (PR), respiration rate (RR) and body temperature (BT) increased with the duration of work. As the pressure increased the animals showed early fatigue symptoms.

Introduction

Donkeys (*Equus asinus*) are amongst some of the under utilized natural power resource of the third world countries. Its seems that the phobia of loosing social prestige among the upper class of the society in using donkeys is the main obstacle in utilizing its full potential. Fortunately its ability to work has been recognized in many countries of the world and is contributing substantially to the well being of the human race in many ways. The fossil fuel and other energy resources of the world are limited and are becoming costlier by the day. This has necessitated the use of renewable energy sources. In India, the power generation and supply is severely affected by many factors which results in intermittent power supply at low voltage particularly in the rural area. This situation can be mitigated by effective utilization of animal power.

The donkey is used mostly as a pack animal for transportation of materials in hilly terrain. Its potential users rarely use the donkey in India for agricultural operations, mostly because of its small size and problem of its social unacceptability. There are certain large breeds of donkeys found in India which show some promise of being useful as farm animals for light farm operations. Donkeys were used as a source of static power for pumping water. A pair of donkeys could pump 3600 litres of water against a head of 10m, in 20 minutes and it needed 0.4 hp power. This quantity of water was found to be sufficient for the domestic needs of 100 persons. Smajstarla *et al.* (1982) have reported that small drip irrigation systems could be operated at 1.5 kg/cm^2 to 2.0 kg/cm^2 pump discharge pressure to irrigate horticultural crops on a small scale. If appropriate harnesses and implements matching the power of this animal are developed, the donkey can prove to be an alternative and cheap source of farm

power for small and marginal farmers. Such a harness modeled on harnesses used for horses used for pulling horse carts (tongas), but appropriately scaled down to the size of donkeys was developed at the Raichur centre of the AICRP on Utilization of Animal Energy. It was felt that donkeys could be used for operations in agricultural production, post-harvest and processing operations and also for small scale irrigation in isolated pockets where provision of an animal power conversion unit is made, to operate a reciprocating pump, using animal power. An animal drawn rotary unit was developed and used in this experiment for lifting water. Donkeys are cheap sturdy and hard working animals as compared to bullocks and other draft animals. Earlier studies have shown that donkeys are capable of producing draft equivalent to about 32% of their body weight as against 14-18% in case of bullocks. Hence, on per unit body weight basis, donkeys are expected to be capable of hauling greater loads than bullocks (Anon., 1993).

Normal physiological responses of donkeys at work, in terms of Pulse rate (PR), Respiration rate (RR) and Body temperature (BT) have been reported. These changes depend upon the type of work, duration of work, draft required, speed of the animal, atmospheric conditions etc. A study on the physiological response of donkeys during an individual agricultural operation generates information pertaining to that particular operation and helps to decide the extent to which the animals can be loaded and the duration for which they can be expected to work, before they are completely fatigued. No information was available on physiological response of donkeys and their work potential in water lifting. Therefore, an experiment was undertaken in the College of Agricultural Engineering at Raichur (Karnataka) under the AICRP on Utilization of Animal Energy, to study the work potential and physiological responses of donkeys during water lifting, during November - December 2001.

Material and Methods

Four large white Indian female donkeys of 725.00-kg total body weight were hitched in tandem to the horizontal input beam of the rotary power transmission unit for the experiment, in order to operate a single barrel-reciprocating pump of 38 mm x 32 mm size. During the period of the experiment the ambient temperature varied from 20°C to 34°C and the Relative Humidity varied from 45 to 60%. The pump had a total suction lift of 3.0 m and total head of 6.0 m.

The rotary animal power transmission unit is essentially meant for turning the direction of input power through 90° and to simultaneously step up the speed, so that the 1.25 to 1.38 input r.p.m. of the animals can be enhanced to a suitable level at the output end of the system where power is tapped to run various machines in a rotary mode of operation. An overall speed ratio of 1 :443.43 is achieved. The details of rotary animal power transmission unit are presented in Fig 1.

Three different pressure heads were created on 1.5 hp reciprocating pump with the help an of adjustable gate valve fixed on the delivery pipe. The pressure created was measured with the help of pressure gauge fixed next to the adjustable gate valve. The pump was operated at three discharge pressure settings of (a) 1.0 kg/cm^2 (b) 1.5 kg/cm^2 and (c) 2.0 kg/cm^2 and the discharge in terms of litres/hour (l.p.h) was calculated, based on the number of minutes and seconds taken to fill a bucket of 20 lit capacity. The readings were noted every 15 minutes i.e., a total of four readings for a given 1 hour work period and the mean value of the discharge was calculated each time. The trials at each discharge pressure setting were repeated two more times at the rate of one trial per day. The work rest schedule followed was 1 hr work followed by 1 hr rest which was repeated cyclically till the animals were found to be completely fatigued at the end

of a particular work period, based upon the fatigue score calculated at the end of each work period.

The measurable physiological responses of the four donkeys, were recorded in terms of the respiration rate (RR), pulse rate (PR) and body temperature (BT) which was noted in the anus. The five qualitative responses, which are not measurable, namely excitement, leg uncoordination, inhibition to progressive movement, frothing and tongue protrusion were noted. The four donkeys were treated as a single team and the arithmatic mean of the initial values of the measurable physiological responses and the same values at the end of each hour of work were calculated to find out the fatigue score. Each of the physiological responses was assigned a numerical value ranging from 1 to 4 and were then to get the fatigue score of the animal team. The added fatigue score table developed by Verma and Singh, (1990) was used to calculate the fatigue score (Table 1).

When the fatigue score reached 16, the team was said to have been completely fatigued and work was stopped for the day. In this manner, tests were conducted for three days, for each discharge pressure setting of the reciprocating pump used in the experiment. For the purpose of tabulation, the mean values of the RR, PR and BT over the three days (replications) have been calculated.

A hydraulic dynamometer of range 0-250 kg was used for recording the draft exerted by the animal team. Observations on walking speed of the animas and the pump discharge were also noted and used to calculate the power output of the animal team during each individual work period, using the formula.

$$\text{Power developed (kW)} = \left[\frac{\text{Draft (kg)} \times \text{Speed (m/s)}}{75}\right] 0.746 \text{...(Michael \& Ojha,1987)}$$

Table1. Fatigue Score table for Donkeys (Verma and Singh, 1990)

	Score scale			
Parameters	**1**	**2**	**3**	**4**
Increase in pulse rate(%)	30	40	70	85
Increase in respiration rate(%)	40	80	130	150
Increase in rectal temperature (%)	3.5	5.0	8.3	9.5
Inhibition to progressive movement	Slow walking	Very slow walking	Stop walking at turns and forcible starting	Unwillingness to continue operation
Leg un-coordination	Occasional dragging of feet	Movement of legs un co-ordination and frequent driving dragging of feet	No co-ordination between fore and hind legs and some times fell down	Unable to move because of un-coordination
Frothing	Dribbling of Saliva starting	Frequent dribbling of Saliva	Continuous dribbling of Saliva	Appearance of froth on upper lips
Excitement	Sudden neck movement	Disturbed	Perspiration	Heavy perspiration
Tongue protrusion	Occasional opening of mouth	Occasional protrusion of tongue	Frequent protrusion of tongue	Continuous protrusion of tongue

Table 2. Pump performance and physiological responses of donkey in team at different discharge pressure settings during water lifting operation (Mean ± SE)

Hours of operation	Working performance				Physiological responses			
	Speed (mls)	Draft (kg)	Power Developed (kW)	Pump discharge (l/hr)	RR (breath/min)	PR (beat/min)	BT (0 C)	Fatigue Score
a) Discharge pressure 1.0 kg/cm²								
Initial	—	—	—	—	17.24±0.68	38.91±0.72	35.67 ± 0. 03	—
I	1.24±0.03	58.33± 1.61	0.72±0.01	5056.66±58.11	23.66±0.81	54.58± 1. 78	35.97 ± 0.06	6.58 ± 0.28
II	1.07±0.05	58.33± 1.61	0.61±0.03	4923.33±26.03	26.33±0.36	58.66± 1.96	36.18 ± 0.13	8. 16 ± 0.64
III	1.03±0.03	58.33±1.61	0.59±0.01	4810.00±26.45	29.25± 0.85	63.99± 1.83	36.57 ± 0.15	9.24 ± 1.06
IV	0.9O±0.02	58.33± 1.61	0.52±0.01	4763.33±135.44	30.88±0.81	67.07±1.05	36.90 ± 0.26	14.66 ± 0.69
V	0.85±0.02	58.33± 1.61	0.49±0.01	4316.66±60.90	32.99±0.98	68.69±0.96	37.15 ± 0.24	16.99 ± 0.36
b) Discharge pressure of 1.5 kg/cm²								
Initial	—	—	—	—	17.74± 0.77	39.83± 0.24	35.80 ± 0.18	—
I	1.21±0.04	65 .20±2.3 7	0.78±0.02	4953.33±37.11	24.83± 0.90	53.32± 1.29	35.98 ± 0.16	7.91 ± 0.20
II	1.07±0.07	65 .20±2.3 7	0.69±0.04	4650.0O±40.41	28.91± 0.41	59.58± 0.98	36.64 ± 0.17	10.74 ± 0.59
III	0.97±0.03	65.20±2.37	0.62±0.01	4283.33±24.04	31.58± 0.51	65.24± 1.32	37.30 ± 0.42	13.82 ± 0.79
IV	0.85±0.05	65.20±2.37	0.45±0.06	4036.66±44.09	33.83± 1.04	69.33± 1.03	37.49 ± 0.21	16.99 ± 0.49
c) Discharge pressure 2.0 kg/cm²								
Initial	—	—	—	—	16.92 ± 0.45	39.91±1.07	35.74± 0.34	—
I	1. 18±0.05	71.00±3.05	0.83±0.02	4726.66 ± 53.64	28.24± 0.34	63.50± 1.93	36.27± 0.39	9.91 ± 0.62
II	0.92±0.03	71.00±3.05	0.65±0.02	4560.00 ± 164.41	33.91± 1.79	69.91±1.58	36.91± 0.21	13.74 ± 1.07
III	0.8O±0.06	71.00±3.05	0.56±0.04	4066.66 ± 88.19	39.33± 0.95	72. 13±1.27	37.69± 0.24	16.74 ± 0.50

Results and Discussion

The data on pump performance and physiological response of the animal team during water lifting at three discharge pressure settings are presented in table 2.

In table 2(a), it is seen from the data that at 1.0 kg/cm² discharge pressure, the animals were able work for a period of 5 hours (5 work periods of 1 hour each, with a rest period of 1 hour at the end of each hour's work), before they got fatigued. At this pressure setting, the draught required to be exerted by the animals was 58.33 ± 1.61 kg. The walking speed of the animals during the 1st working period of 1 hour was 1.24 ± 0.03 kmph. At this draft and walking speed, the animal team developed 0.72± 0.01 kW and the pump gave a discharge of 5056.66 ± 58.11 lph.

It was seen that during the subsequent work periods, the walking speed of the animal team declined from 1.24± 0.03 m/s to 1.07 ± 0.05 m/s during the 2nd work period, 1.03 ± 0.03 m/s during the 3rd work period, 0.90 ± 0.02 m/s during the 4th work period and to 0.85 ± 0.02 m/s during the 5th work period, at the end which the animals got completely fatigued. The power developed by the animals declined from 0.72 ± 0.01 kW during the 1th work period to 0.61 ± 0.03 kw, 0.59 ± 0.01 kw, 0.52 ± 0.01 kw and 0.49 ± 0.01 kW during the 2nd, 3rd, 4th and 5th work periods respectively. During the same period, the pump discharge declined from 5056.66 ± 58.11 lph to 4923.33 ± 26.03 lph, 4810.00 ± 26.45 lph, 4763.33 ± 135.44 lph and 4316.66 ± 60.90 lph during the 2nd, 3rd, 4th and 5th work periods respectively.

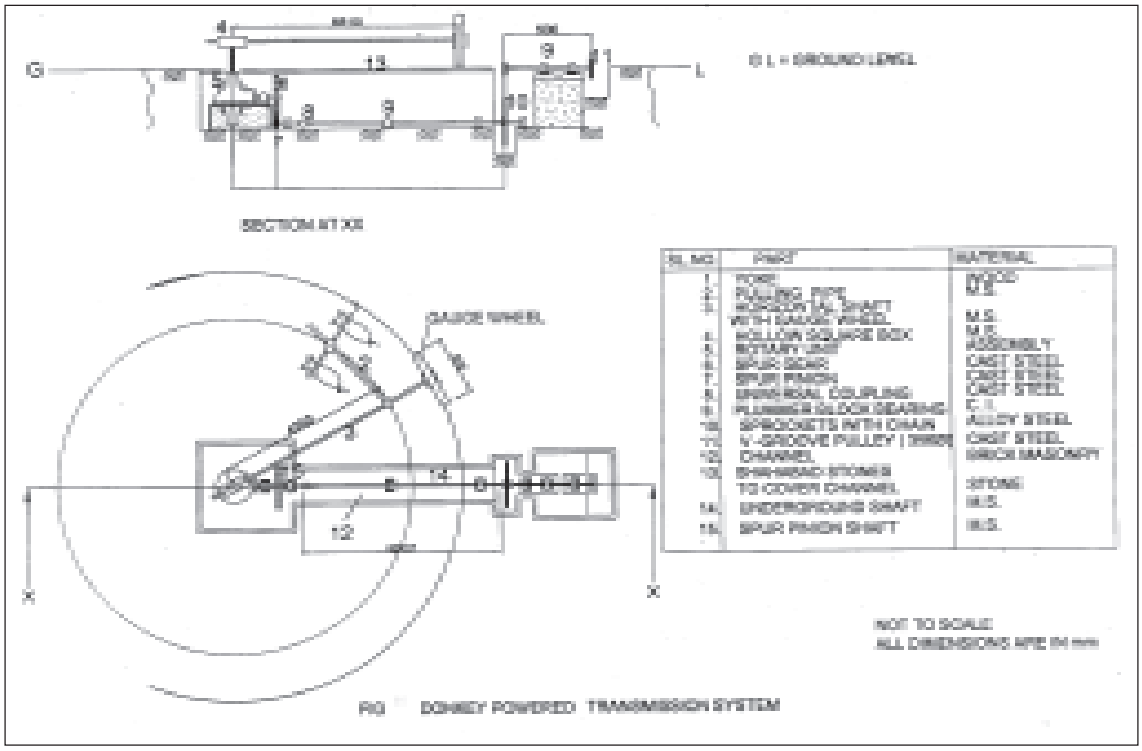
During the same period, the mean respiration rate of the animal team increased from an initial value of 17.24 ± 0.68 breaths per minute to 23.66 ± 0.81, 26.33 ± 0.36, 29.25 ± 0.85, 30.88 ± 0.81 and 32.99 ± 0.98 breaths per minute at the end of the 1st, 2nd, 3rd, 4th and 5th work periods respectively.

Similar trends were observed in pulse rate, wherein it increased from the initial value of 38.91 ± 0.72 beats/minute to 54.58 ± 1.78, 58.66 ± 1.96, 63.99 ± 1.83, 67.07 ± 1.05 and 68.69 ± 0.96 beats per minute at the end of the 1st, 2nd, 3rd, 4th and 5th work periods respectively. The body temperature increased from the initial value of 35.67 ± 0.03 °C to 35.97 ± 0.06 °C, 36.18 ± 0.13 °C, 36.57± 0.15 °C, 36.90 ± 0.26 °C and 37.15± 0.24 °C at the end of the 1st, 2nd, 3rd, 4th and 5th work periods respectively. The mean points scored by the animal team on the fatigue score at the end of the first work period were 6.58 ± 0.28, which increased to 8.16 ± 0.64, 9.24± 1.06, 14.66 ± 0.69 and 16.99 ± 0.36 at the end of the 2nd, 3rd, 4th and 5th work periods respectively. Since the fatigue score of 16.00 was crossed, the animal team was said to be fatigued and they were rested for the day.

At the discharge pressure of 1.5 kg/cm^2 the animals were able to work for a period of 4 hours before they got fatigued. The data on performance and physiological response of the animals at the 1.5 kg/cm^2 pressure is shown in table 2(b). At this pressure setting, the draft required to be exerted by the animals was 65.20 ± 2.37 kg. The walking speed of animals during the first working period of one hour was 1.21 ± 0.04 m/s. At this draft and walking speed, the animals developed 0.78 ± 0.02 kW power and the pump gave a discharge of 4953.33 ± 37.11 Iph. It was seen that subsequently the animals" walking speed declined from 1.21 ± 0.04 m/s at the end of the first one hour working period to 1.07 ± 0.07 m/s during the 2nd working period, 0.97 ± 0.03 m/s during the 3rd working period and 0.85 ± 0.05 m/s during the 4th working period, at the end of which the animal team got completely fatigued. The power developed declined ftom 0.78 ± 0.02 kW during the first working period to 0.69 ± 0.04, 0.62 ± 0.01 and 0.45 ± 0.06 kW during the 2nd, 3rd and 4th working periods, respectively. The pump discharge declined from 4953.33 ± 37.11 Iph during the 1st working period to 4650± 40.41, 4283.33 ± 24.04 and 4036.66 ± 44.09 Iph during the 2nd, 3rd and 4th working periods respectively.

During the same period, the mean respiration rate of the animal team which was initially 17.74 ± 0.77 breaths per minute, increased to 24.83 ± 0.90, 28.91 ± 0.41, 31.58 ± 0.51 and 33.83 ± 1.04 breaths per minute at the end of the 1st, 2nd, 3rd and 4th working periods respectively. Similar trends were observed in case of pulse rate (39.83 ± 0.24 beats per minute initial value to 53.32 ± 1.29, 59.58 ± 0.98, 65.24 ± 1.32 and 69.33 ± 1.03 beats per minute at the end of 1st, 2nd, 3rd and 4th working periods respectively) and body temperature also (35.80 ± 0.18 °C initial value to 35.98 ± 0.16, 36.64 ± 0.17,37.30 ± 0.42 and 37.49 ± 0.21 °C at the end of the 1st, 2nd, 3rd and 4th work periods respectively). The mean points scored by the animal team on the fatigue score at the end of the 1st hour of work was 7.91 ± 0.20 and the same increased to 10.74 ± 0.59, 13.82 ± 0.79 and 16.99 ± 0.49 at the end of 2nd, 3rd and 4th working period respectively. At this point the animal team was completely fatigued and the animals were rested for the day. The results were similar to those that were observed at the 1.0 kg/cm^2 discharge pressure setting of the pump.

At the discharge pressure of 2.0 kg/cm^2 , the animals were able to work for a period of 3 hours (three work periods of 1 hour each with 1 hour rest between two work periods), before they got fatigued. The data on pump performance and physiological response of the animal team at 2.0 kg/cm^2 pressure setting is shown in table 2 (c). At this pressure setting, the draft required to be exerted by the animals was 71.00 ± 3.05 kg. The walking speed of the animals during the 1st working period of 1 hour was 1.18 ± 0.05 m s. At this draft and walking speed, the animals developed 0.83 ± 0.02 kW power and the pump gave a discharge of 4726.66 ± 53.64 Iph. It was seen that subsequently the walking speed of the animal



team declined from 1.18 ± 0.05 mls during the 1st working period to 0.92 ± 0.03 and 0.80 ± 0.06 m/s during the 2nd and 3rd working periods respectively, at the end of which the animals got completely fatigued. The power developed by the animals declined from 0.83 ± 0.02 kW during the 1st working period to 0.65 ± 0.02 and 0.56 ± 0.04 kW during the 2nd and 3rd working periods respectively.

During the above period, the pump discharged declined from 4726.66 ± 53.64 lph during the first work period to 4560.00 ± 164.41 and 4066.66 ± 88.19 lph during the 2nd and 3rd work periods respectively.

During the same period, the mean respiration rate of the animal team, which was initially 16.92 ± 0.45 breaths per minute, increased to 28.24 ± 0.34,33.91 ± 1.79 and 39.33 ± 0.95 at the end of 1st, 2nd and 3rd working periods respectively. Similar trends were observed in case of pulse rate (39.91 ± 1.07 beats per minute initial value to 63.50 ± 1.93, 69.91 ± 1.58 and 72.13 ± 1.27 beats per minute at the end of the 1st 2nd, and 3rd working periods respectively) and body temperature (35.74 ± 0.34 °C initial value to 36.27 ± 0.39, 36.91 ± 0.21 and 37.69 ± 0.24 °C at the end of the 1st, 2nd and 3rd working periods respectively). The mean points scored by the animal team on the fatigue score at the end of the 1st hour of work was 9.91 ± 0.62 and the same increased to 13.74 ± 1.07 and 16.74 ± 0.50 at the end of the 2nd and 3rd working periods respectively. At this point, the animal team was completely fatigued and the animals were rested for the day. The results were similar to those that were observed at the pressure settings of 1.5 and 2.0 kg/cm^2.

In general, a decline in walking speed, power developed and pump discharge was observed with increasing work duration at each of the three discharge pressure settings. On the other hand, the respiration rate, pulse rate, body temperature and points scored on the fatigue

score increased with duration of work at each of the three discharge pressure settings of 1.0, 1.5 and 2.0 kg/cm^2. With increase in the discharge pressure, the walking speed of the animals and discharge decreased and the power needed to be developed by the animals increased. Moreover, the number of work periods for which the animals could work before they crossed the fatigue score of 16.00 also decreased with increase in discharge pressure. These findings are similar to the findings on fatigue score of animals reported by Hallikeri *et al.* (1997), for sowing and harrowing operations, using donkey power.

The above results show that donkeys have a good potential for use as a source of power for operating small reciprocating pumps in areas where water is available in small isolated pockets and providing electricity supply is also not practical due to the excessive cost of the electricity supply network and the small volumes of water available. In such cases, it is worth using a donkey powered reciprocating pump to provide drip irrigation to appropriate horticultural crops on a small scale, by using a system which works on 1.5 to 2.0 kg/cm^2 pressure.

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