An ergonomic intervention in operation of a pedal operated Ragi (Eleusine Coracana) thresher

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Abstract: Finger millet (ragi) is a staple food of tribal Indian community of poor socioeconomic condition. Traditionally finger millet is threshed by beating method which is very tedious, labour intensive, time consuming and less efficient method where energy expenditure is high. As per ergonomic evaluation foot operated equipment are of less drudgeries than the hand operated equipment. Thus the development of pedal operated ragi thresher was justified for the tribal community. Ergonomic evaluation of the pedal thresher was conducted and physiological characteristics like working heart rate (WHR), Oxygen consumption rate (OCR) and Energy expenditure rate (EER) were observed as 126.3 beats/min, 0.95 l/min, 20.6 kJ/min respectively in case of traditional beating method and 108.2 beats/min, 0.6 l/min, 12.5 kJ/min, respectively in case of pedal thresher. Significant reduction of ΔHR from 51 to 33 beats/min was observed with operation of pedal thresher which was highly within the limit for continuous performance (LCP). Overall discomfort rate was observed as 5.6 in case of pedal operated ragi thresher as compared to 8.5 in case of beating method. Threshing capacity and threshing efficiency of the thresher was obtained as 24 kg/h and 92.2% compared to 6 kg/h and 80% in case of beating method. From the results, it was concluded that the pedal thresher is a much better option for threshing of finger millet as compared to the traditional threshing method.
Key words: Finger millet, Tribal, Working heart rate, ΔHR, Oxygen consumption rate

1 Introduction

Finger millet (ragi) is a staple food of tribal Indian community of poor socioeconomic conditions. India is an amalgam of 437 tribes and they occupy 15% area of the country and 9.7% of population. The states having major tribal people are Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharastra, Odisha, Rajasthan, Tamil Nadu, West Bengal and some north-eastern states. They consume ragi in the form of powder, cooked cake, mudde, ambali, puddings, porridge, dosa, rotis etc. They consume ragi powder with milk, boiled water and yoghurt.

Traditionally ragi is threshed by beating method and treading under the feet of animals. Ragi is also threshed by the power thresher available in India. In the beating method the workers have to lift the stick and put that repeatedly on the ragi ear heads present on

the hard surface for the separation of the ragi grains from the chaff. By using their muscle power. This operation is very tedious, time consuming, inefficient, uneconomical, produces low quality product. Repeated lift of the stick also causes pain in the arms. The workers do the job in squatting position for long times which causes pain in thigh, legs and feet. Energy expenditure in this operation is very high. The land holding of the tribal people is very low and they are also economically very poor. In some tribal areas electricity is not present and in many areas it is very irregular. Transportation of fuel to the tribal areas is a very difficult job due to lack of communication. According to the previous study pedal operated equipments require less energy than the hand operated equipments [1, 5, 8]. Therefore a pedal operated ragi thresher was developed and compared with the manual threshing method.

2 MATERIALS AND METHODS

A pedal operated ragi thresher was developed as per the requirement of the tribal people. It was evaluated and physiological response during the operation was obtained as shown in figure 1 and compared with the response taken during the manual beating method. The optimal power output and pedalling rate for Indian agricultural workers were obtained as 60W and 50 rev/min [6, 7]. So the speed of 40 rev/min was taken which is lower value than optimum speed for the development of thresher which is sufficient for the threshing of ragi ear heads. The power was transmitted from the pedal to the threshing cylinder by the use of the chain drive.

Fig. 1 Evaluation of the pedal operated ragi thresher

Physiological response of twenty one male workers was obtained during the operation of the thresher and also during the beating method. Before the experiment was conducted physiological response of each subject was checked for cardiovascular, neurovascular and musculoskeletal disorders. Some basic physiological characteristics like age, weight, stature and maximum heart rate were measured in the laboratory. Weight was measured by using the weighing balance (100 kg capacity with least count 0.1 kg). Stature was measured by the stadiometer (Least count 1 mm). Maximum heart rate of subjects was obtained by using the equation "220− age (yrs)". The data were presented in the Table 1.

ISBN 978-93-5258-836-7

Table 1 Physiological characteristic of the selected subjects

Particulars	Range	Mean value ± S.D
Age, Years	20 – 45	31.67 ± 8.91
Weight, Kg	53 – 65	59.78 ± 3.80
Height, cm	159 –178	167.68 ± 5.86
BMI, kg/m^2	17 – 24	21.33 ± 2.11
Av. Predicted HRmax (beats/min)	175 – 200	188.33 ± 8.91

Physical properties of the ragi ear heads and grains of Chilika variety were obtained which was used for the threshing operation. The data were presented in the Table 2.

Table 2 Physical properties of ragi ear heads and ragi grains

Sl. No.	Physical properties	No. of sample	Min	Max	Mean	Standard deviation
	Ragi Ear heads					
1	Length (mm)	10	43.00	89.00	71.10	14.76
2	Width (mm)	10	24.00	42.00	33.20	5.22
3	Thickness (mm)	10	14.00	31.00	17.50	5.31
4	Coefficient of static friction	10	0.17	0.19	0.17	0.01
5	Bulk density (g/cm^3)	10	1.50	1.54	1.52	0.01
6	Carrying velocity of the chaff (m/s)	10	2.20	2.60	2.37	0.12
7	Moisture content (%)	05	13.12	14.00	13.51	0.25
	Ragi grain					
1	Diameter (mm)	20	1.59	1.67	1.63	0.02
2	Sphericity (%)	10	66.70	69.80	68.60	0.92
3	1000 grain weight (g)	10	2.63	3.72	3.00	0.29
4	Bulk density (g/cm^3)	10	0.74	0.83	0.81	0.02
5	True density (g/cm^3)	10	1.39	1.49	1.42	0.02
6	Porosity (%)	10	40.80	47.60	43.13	2.44
7	Angle of repose (°)	10	34.01	34.34	34.13	0.12
8	Static coefficient of friction	10	0.12	0.14	0.13	0.01
9	Terminal velocity of the grain (m/s)	10	4.30	4.70	4.46	0.12
10	Compressive strength of the grain (N)	10	16.83	20.43	18.30	1.33
11	Moisture content (%)	05	11.83	12.69	12.43	0.28

Working heart rate (WHR) was measured by using the polar heart rate monitor and the data were recorded from 6th minute to 15th minute of the operation at 2 minute interval during the operation both by thresher and beating method. The oxygen consumption rate was measured by using K4b2 and the energy expenditure was calculated by using the equation "EER= OCR x 20.9". After the 15 minute of performance the subjects were asked to take rest till the heart rate falls to the normal value. After 15 minute of operation the subjects were asked to rate their overall discomfort rating by using visual analogue discomfort scale developed by Leg and Mahanty in which 0 is no discomfort and 10 is extreme discomfort.

The physiological data obtained during the performance were statistically analysed by using

factorial Randomized block design (RBD) and analysis of variance (ANOVA) was used for comparing the results.

3 RESULTS AND DISCUSSION

The thresher was operated by workers and during threshing performance parameters like threshing capacity, threshing efficiency, damaged grain and grain loss were obtained and physiological response of the workers were collected and compared with the response during beating method. Table 3 and 4 presents the values obtained during the evaluation.

3.1 Performance parameters during threshing of ragi by the pedal thresher and beating method

Threshing capacity is the amount of grain threshed per unit time. Threshing capacity of the thresher was obtained as 24 kg/h whereas it was 6 kg/h in case of beating method which shows 75 % increase of capacity. The reason may be the speed of threshing with the thresher and non uniformity of putting the stick. Speed of threshing by beating method was very slow as compared to the thresher and also not constant. Repeated putting of stick caused stress and fatigue to the operator which reduced the threshing capacity. When an operator put the stick on the crop, the force and uniformity of putting the stick was not uniform which caused the reduction of threshing capacity. Statistical analysis was done which shows that threshing capacity by beating method was significantly different from the threshing capacity of thresher. ANOVA for the two operation indicated that the methods of threshing affected the threshing capacity.

Threshing efficiency is the ratio of threshed grain collected at the main grain outlet and total input of the crop. The threshing efficiency was obtained as 92.2% on average in case of thresher, which is 80% in case of beating method. In case of beating method the force was not uniform on the entire crop during threshing which resulted in the low threshing efficiency. In case of thresher impact and rubbing force on the crop was uniformly distributed on the entire crop during threshing which resulted in better threshing. Statistical analysis was done which shows the significant difference between threshing efficiency in both the method. Also the ANOVA for the two operation indicated that methods of threshing affected the threshing efficiency.

Grain damage was obtained during both the threshing method which shows the average value of 2.3% but in case of beating method 6.4%. The reason behind this may be the direct contact of stick with the seeds after threshing when it was present with the unthreshed crop for threshing. Also may be due to apply of greater force on the crop sometimes. Statistical analysis also showed the significant difference between grain damage during both the threshing methods. ANOVA for both the method also indicated that method of threshing affected the grain damage during threshing.

Grain loss is the threshed grain lost with the chaff. Average grain loss in case of thresher was observed as 2.5% but in case of beating method it was 8.3%. Due to the small size of the grain after threshing some grains cannot be collected from the ground and some

 ISBN 978-93-5258-836-7

grains were lost with the chaff during the cleaning after threshing. Statistical analysis was done which shows the statistical difference between grain loss after threshing by both the methods. ANOVA of both the data indicated that threshing method affected the grain loss.

Table 3 Performance analysis of threshing by pedal thresher and beating method

Sl No	Parameters	Pedal thresher	Beating method
1	Threshing capacity (kg/h)	24	6
2	Threshing efficiency (%)	92.2	80
3	Grain damage (%)	2.3	6.4
4	Grain loss (%)	2.5	8.3

3.2 Physiological response during both the threshing methods

Physiological response of the workers during the threshing operation by both the method (pedal thresher and beating method) was collected and compared.

The average working heart rate from 6th minute to 16th minute of continuous operation of selected workers during the threshing operation by the thresher and also the beating method with the help of polar heart rate monitor due to the reason of stabilisation of WHR after 6th minute of operation [3, 9]. The mean value of working heart rate of the subjects both the threshing methods (thresher and beating method) were obtained as 108.2 beats/min and 126.3 beats/min during threshing operation by thresher and beating method respectively. The ΔHR over resting heart rate in case of beating method (51.3 beats/min) was higher than the accepted limit for continuous work for Indian agricultural workers (40 beats/min) but in case of pedal thresher it was 33 beats/min which is within the limit. The reason behind this may be the more requirement of strength. During the beating method hand strength was used and force was applied continuously. But when threshing operation was done by thresher pedal strength was used. Researchers obtained the result that pedal strength is more than the hand strength and less strength is required to apply the same force [4]. The working heart rate was influenced highly significantly by method of threshing at 5 per cent significant level as obtained from ANOVA by the statistical analysis.

Average oxygen consumption rate of workers were measured during both beating method and threshing with the thresher by the help of K4B2. The mean values of the Oxygen consumption rate (OCR) during both threshing method were 0.954 l/min and 0.598 l/min in case of beating method and thresher.OCR of the workers was very high during the threshing of ragi by beating method as compare to the threshing by the thresher may be due to the reason that during the beating method high energy was required to apply the force and for high energy high oxygen consumption is required and OCR increases with the increase of heart rate [2]. So OCR is high during beating than with the thresher. ANOVA showed that the OCR was influenced highly significantly by method of threshing.

Overall discomfort rating (ODR) of the workers was done which showed that it was

8.44 and 5.68 during beating method and threshing with the thresher respectively. ODR of the workers were very high during the threshing of ragi by beating method as compare to the threshing by the thresher may be due to the reason that during the beating method the person had to do the operation in squatting posture. So the discomfort was very high. But during the threshing operation with the thresher the person had to sit on the seat and pedal the thresher by his pedal strength. Hence ODR was low during the threshing with the thresher. The statistical analysis was done and the ANOVA indicated that the ODR was influenced significantly by the method of threshing at 5% significance level.

Table 4 Physiological response during the threshing operation by thresher and beating method

Sl No	Parameters	Pedal thresher	Beating method
1	Working heart rate (beats/min)	108.2	126.3
2	ΔHR(beats/min)	33	51.3
3	Oxygen Consumption Rate (l/min)	0.598	0.984
4	Energy Expenditure Rate (kJ/min)	12.5	20.6
5	ODR (10 point scale)	5.68	8.44

4 CONCLUSION

The ergonomic performance parameters were evaluated for the traditional beating method and for the pedal thresher where working heart rate (WHR), Oxygen consumption rate (OCR) and Energy expenditure rate (EER) were recorded and statistically analyzed for both. From the results, ΔHR was found 33 beats/min which is within the acceptable limit of limit of continuous performance (LCP) in case of pedal thresher along with ODR being less in case of pedal thresher. The energy expenditure rate during threshing with thresher was also found low as compare to traditional threshing method. The conclusion from the study was drawn that the pedal operated ragi thresher was definitely a better option than the beating method for threshing of ragi which showed huge decrease in the physiological cost during the operation and a considerable reduction in discomfort rate along with much lesser fatigue and muscle pain compared to traditional beating method.

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