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A study on bullock energy utilization through rotary mode power transmission system in operating potato peeler and slicer for chips making as value added product of potato

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ABSTRACT : Use of bullocks for agricultural work is limited to tillage, sowing and transportation. The total annual use of bullocks in the state of Odisha is less than 300 hours even though the annual potential use is nearly 800 hours. To enhance the utilization of bullocks, there is a need of using bullock power operated stationary machines requiring about 1 hp (0.8 kW) power for doing various post harvest operations in rotary mode like paddy threshing, paddy winnowing, chaff cutting, sugarcane crushing, groundnut decortications, oil expelling, pulse milling and dehusking etc. This would ultimately reduce the economic burden of maintaining bullocks. With this aim, a study was conducted during the year 2012 for operating a potato peeler and slicer with the help of the rotary gear complex, installed in the premises of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha. The experiments were conducted continuously for 3 hours (8 am-11 am) with the work rest cycle of 1hour work + 20 minutes rest + 1 hour work +30 minutes rest + 1 hour work. The measurement of physiological responses like respiration rate, heart rate, body temperature etc. of the small sized non-descript breed of bullocks (pair body weight of 450 kg) of Odisha were done at half an hour interval and calculation of the corresponding fatigue scores to know their comfortable working without inflicting any health hazards. The mean draft requirement of the potato peeler and slicer was found to be 7.70 % and 6.40 %, respectively in terms of percentage of body weight of the small size bullocks which were within their draftability. The highest fatigue scores during the operation of peeler and slicer were 18 and 17, respectively which were below the threshold fatigue score of 20. The output of potato peeler and slicer in rotary mode was observed to be 160 kg/h and 73 kg/h, respectively as against their corresponding values 200 kg/h and 100 kg/h in electrically operated motor and only 7 kg/h in manual peeling and slicing with the help of a knife. The operation of potato peeler and slicer through rotary mode was not found to be economical as compared to when operated with electric motor. Nevertheless, it was a meaningful utilization of animal power during the idle period in farm operations and to compensate the maintenance cost of the bullocks.

KEY WORDS : Bullock power, Potato peeler and slicer, Physiological responses of bullock, Fatigue score, Mechanical gear system, Rotary mode of operation

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Peeling of potato is one of the important operations in potato processing for chips making and the optimum yield greatly relies on the efficiency and effectiveness of the method followed. Potato, besides being used as a daily food item in the diet, today it is very popular being used in the form of chips as snacks food. The potato chips are at present one of the widely used processed food items that give considerable value addition to potatoes (Anonymous, 2011). For making chips, the important preparatory operations are washing, peeling and slicing. Traditional method of hand peeling and slicing with the help of a knife is tedious and time consuming. Moreover, the loss of peel and flesh is high resulting in poor peeling and slicing efficiency. Many of the potato processing industry uses lye peeling in which a heat ring is formed below the surface of the potato due to tissue damage and ploypherol enzyme activity that deteriorate the quality of the chips (Ezekiel *et al*., 2003). It is, therefore, not recommended for making

chips with the above method and also a costly affair at small scale level.

Annual post harvest losses of potato vary from 20 to 40 % mainly due to inadequate storage facilities in rural areas (Khurana, 2009). The potato growers are very often forced to sell their produce at a very low price. To avoid distress sell and to get remunerative price, farmers are now more attracted towards processing of potatoes at their own level. Thus there is a need for development of suitable low cost mechanical devices for helping the farmers at rural level to go for chips making ensuring additional profit. Although low horse power capacity potato peeler and slicers are at present available commercially, but getting a suitable prime mover to operate the machine is a major constraint. Grid connected power supply is still not available in many of the remote areas of the country and in some areas where it is available, its supply is most irregular and erratic causing a great problem of using power driven machines in right time. A pedal operated potato peeler and slicer (Chand *et al*., 2013) though developed by G.B. Pant University of Agriculture and Technology, Pantnagar is not available commercially and its capacity is low *i.e.* in the range of 55-65 kg/h with speed of the machine shaft of 30-45 rpm depending upon the capability of the operator. Keeping the above facts in mind, there is the need for searching of an alternative and sustainable source of energy to operate the machine at the farmers' level. Draft animal power may be a viable option for the purpose.

Draft animal is still a major source of farm power in Indian agriculture (Singh and Singh, 2013). Bullock and buffalo are the common draft animals found in our country with a total population of 55 millions in 2008-09 (Anonymous, 2013). These animals perform different field operations and are also used for rural transportation. It is observed that bullocks are generally utilized for about 300 hours in a year (Srivastava, 2000). They remain idle for rest of the time. Farmers have to maintain and take care of the animals throughout the year whether or not they are employed in gainful activity. Increased use of draft animal can add to the income of the farmers and also reduce the dependence of commercial fuels which are now-a-days getting costlier. One feasible way of harnessing draft animal is through operating different stationary agro-processing machines like thresher, winnower, chaff cutter, cane crusher, grain grinder, oil expeller etc. in rotary power transmission system (Doshi and Tiwari, 2008). In the state of Odisha, about 78 per cent of farmers are coming under marginal and small categories and they fully depend on the draft bullocks for doing various farm operations (Ghosal *et al*., 2012). However, small size bullocks having a pair body weight of about 450 kg are mainly found in most of the regions of the state (Behera *et al*., 2006). The present study, therefore, aims at the use of bullock energy particularly during idle period of bullocks so that their annual use would be increased and ultimately economic burden of maintaining them would be reduced. Further, it would also provide useful information on the suitability of small size bullocks of Odisha in operating agro-processing machines including potato peeler and slicer in rotary mode of power transmission system.

METHODOLOGY

The rotary gear unit installed in the premises of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar was used for the study. The details of the components of the rotary unit are given below:

Gear box:

The gear box made of 6 mm thick pressed mild steel plate, is rectangular in shape with a dimension of 660 x 579 x 274 mm (Fig. 1). Different parts of the gear units are assembled inside the box.

Spur gears:

The spur gear is made of heat treated alloy steel having module 4.0 mm. The spur gear has 77 teeth while the spur pinion has 16 teeth. The speed ratio of 1: 4.8 is obtained. The set of spur gears transmits the power between two parallel shafts.

Bevel gears:

Bevel gears are spiral tooth gear having 6.5 mm module that transmits the power at 90^0. The bevel gear has 43 teeth, while the bevel pinion has 7 teeth. It is made up of heat treated alloy steel. The speed ratio is 1: 6.14. Combination of bevel and spur gear can produce the speed ratio of 1:29.56.

Shafts:

There are three shafts in the bevel gear assembly. The first shaft of bevel gear is held in vertical position. Its diameter is 50 mm at the bottom side and 63 mm at top side. The second shaft for bevel pinion and spur gear is 50 mm in diameter. The third shaft used for bevel pinion is 30 mm in diameter.

Bearing:

One ball bearing 90 x 50 x 24 mm size is fitted on the 50 mm shaft and another ball bearing of 72 x30 x 20 mm size is fitted on top of the same. One thrust bearing (60 x 38 x 20 mm size) is fitted at the outer end of the pinion shaft with two ball bearings of 72 x 30 x 20 mm and 88 x 45 x 22 mm size.

Bearing cover:

One bearing cover is used for thrust bearing of 60 x 38 x 20 mm size. The cover is made of 45C8 steel.

Bushes:

Two bushes are used in the input shaft with necessary lubrication arrangement. One is fixed at the bottom plate of the box and the other is fixed at the cover plate.

Belt pulley transmission unit:

The speed ratio of output shaft of the gear box is 1:29.56. There are two transmission shafts (first drive shaft and counter shaft), mounted on two pillars each. The diameter of the shaft is 50 mm. The first drive shaft is connected to the output shaft of the gear box through universal joint coupling. One pulley of 60 cm is mounted on the first drive shaft and the counter shaft is having a pulley of 15 cm and other pulleys of various sizes. The pulley of 60 cm size in the first drive shaft is connected to 15 cm size pulley in counter shaft with the help of flat belt thereby stepping up the speed in the ratio of 1:4. For potato peeling in potato peeler, the first step up speed ratio from the first drive shaft to counter shaft is in the ratio of 1:4, from counter shaft (40 cm pulley) to peeler shaft (25 cm pulley) is 1:1.6. Hence, the final speed ratio from the output shaft of gear box to the output shaft of potato peeler is 1:190. Similarly, for potato slicing in potato slicer, the step up speed ratio from the first drive shaft to counter shaft is in the ratio of 1:4, from counter shaft (40 cm pulley) to slicer shaft (23 cm pulley) is 1:1.74. Hence, the final speed ratio from the output shaft of gear box to output shaft of potato slicer is 1:206.

Ratchet assembly :

One ratchet assembly is provided with the gear box (Fig. A) in order to prevent the back flow of power to the bullocks when they suddenly stop during working. By this unit, the input shaft from the bullocks stops rotating when the bullocks stop moving but the gear unit and the connected shafts keep on rotating due to their inertia.

Fig. A : Gear box unit for mechanical power transmission in rotary mode

Potato peeler and slicer :

A potato peeler and slicer procured from M/S Mill and Machinery, Bauxi Bazar, Cuttack, Odisha was used for peeling as well as slicing of potato through rotary mode of operation by using bullock power. The potato peeler was tested continuously for 3 hours with a suitable work rest cycle like 1hour work + 20 minutes rest + 1 hour work +30 minutes rest + 1 hour work. The same machine can otherwise be operated with one hp motor. The slicer was used after peeling work was over. The experiment was conducted continuously for 3 hours from 8 am to 11 am by following the above work rest cycle. The measurement of physiological responses like respiration rate, heart rate, body temperature etc. of the small size non-descript breed of bullocks (pair weight of bullocks 450 kg) of Odisha were taken at half an hour interval and calculation of fatigue score were done to know their comfortable working without inflicting any health hazards. One person was employed both for peeling and slicing work one after another and one bullock operator was engaged for controlling a pair of bullocks in test track of the rotary unit. Standard techniques were used for measurement of the different parameters. The following observations were taken at half an hour interval.

Rotary gear parameters :

Power transmission system.

Gear ratios at various units of the rotary system.

Bullock parameters :

Speed of bullocks (km/h)

Average draft (N)

Power output (kW)

Physiological responses

Fatigue score.

Machine parameters (potato peeler and slicer) :

RPM of the shafts of the machine

Peeling efficiency (per cent)

Out put capacity (kg/h)

Cost of operation (Rs./h).

The cost of operation was calculated both for peeling as well as slicing in rotary mode of operation through bullocks and compared with electrically operated motor. The following assumptions were taken for calculating the cost (Table A).

Variable cost for potato peeling and slicing: One person and one bullock operator with labor charge Rs. 150/ day of 6 hours per person. The details specifications of potato peeler and slicer are given in Tables B and C. Photographs of operation of potato peeler and slicer through rotary mode by using bullock power are given in Fig. B and C.

The load cell was mounted between the beam and yoke

Table A : Assumptions for computing cost of operation

Units	Cost, Rs	Life span	Repair and maintenance	Annual use, h
Rotary unit	30,000	10	5 % of the cost	960
Potato peeler	12,000	10	-do-	240
Potato slicer	10,500	10	-do-	240
1 hp electric motor	6,500	10	-do-	240
Bullock pair	20,000	5	Rs.5/h	1200

Table B : Salient specifications of the potato peeler

Sr. No.	Components	Dimension
1.	Length, mm	1120
2.	Breadth, mm	500
3.	Height, mm	1120
4.	Weight, kg	39
5.	Feeding unit (length x width), mm	360 x 120

Table C : Salient specifications of the potato peeler

Sr. No.	Components	Dimension
1.	Length, mm	290
2.	Breadth, mm	220
3.	Height, mm	230
4.	Weight, kg	6
5.	Feeding unit (length x width), mm	220 x 170

Fig. B : Operation of potato peeler through rotary mode

through rope to measure pulling force. The horizontal component of pull was calculated for draft of the bullock by taking angle of inclination of rope with the line of travel. Speed of bullocks was determined by recording the time to travel one circle in rotary test track. The power requirement was calculated by using the following equation:

$$P = \frac{FS}{3.6} \quad (1)$$

where, P = power in kW; F= draft force, kN and S = speed, km/h

Fig. C : Operation of potato slicer through rotary mode

Similarly, the peeling efficiency was calculated by using equation (2).

$$\text{Peeling efficiency \%} = \frac{\text{Weight of total peeled potato after peeling}}{\text{Weight of total potato fed to peeler before peeling}} \times 100 \quad (2)$$

The physiological parameters of working bullocks such as heart rate, respiration rate, rectal temperature and fatigue symptoms were recorded at the start of the work and after every half an hour of work. Observations on physiological parameters were taken by following the method mentioned below:

Heart rate (beats/min):

By sensing palpitation/min of the bullock at coxygeal artery at the rear of the tail.

Respiration rate (breaths/min):

By counting nos. of air exhaled/min by the bullock.

Rectal temperature (^{0}C):

By inserting a clinical thermometer in the anus at 50 mm inside.

The sequence of observations on visual fatigue symptoms were recorded as per the fatigue score card (Upadhyay, 1987).

■ RESULTS AND DISCUSSION

The results of the experiment for potato peeler and slicer are presented in Tables 1 and 2, respectively.

Environmental parameters:

The ambient air temperatures at the beginning of the

experiments at 8 AM were 27 ^{0}C and 25 ^{0}C for potato peeler and slicer while the same at the end of the operation at 11 AM were 40.5 ^{0}C and 40 ^{0}C, respectively. Similarly, the relative humidity at the beginning of the experiments at 8 AM were 42 % and 38 % for potato peeler and slicer, respectively while at the end of the operation at 11 AM, the values remained same *i.e.* 22 % for the both. Environmental parameters are important for such operations, as physiological responses of bullock are predominantly affected by ambient conditions (Behera *et al*., 2006).

Physiological parameters:

The pulse rate (48 bpm), respiration rate (16 bpm) and body temperature (37.4 ^{0}C) at the beginning of the operation significantly (P = 0.05) increased to 90 bpm pulse rate, 48 bpm respiration rate and 38.9 ^{0}C body temperature of the bullocks registering an increase of 87.5 %, 200 % and 4.01 %, respectively at the end of operation in case of peeler. Similarly, the pulse rate (50 bpm), respiration rate (14 bpm) and body temperature (37.3 ^{0}C) at the beginning of the operation significantly (P = 0.05) increased to 86 bpm pulse

Table 1 : Performance of potato peeler in rotary mode

Parameters	Duration, h							Mean
	In	0.5	1.0	1.5	2	2.5	3.0	
Pulse rate, bpm	48	60	66	72	80	84	90	71.42
Respiration rate, bpm	16	22	32	34	44	46	48	34.57
Body temp, ^{0}C	37.4	38.1	38.3	38.4	38.5	38.7	38.9	38.32
Amb Temp., ^{0}C	27	29	31.0	33.4	35.2	38.6	40.5	33.52
Rh, %	42	38	34	28	26	24	22	30.57
Draft, kg	-	38	36	36	34	32	32	34.66
Percentage body weight	-	8.44	8	8	7.55	7.11	7.11	7.70
Draft, N	-	372.78	353.16	353.16	333.54	313.92	313.92	340.08
RPM of bullocks/0.5h	-	58	56	52	52	50	44	52
RPM at peeler shaft	-	290	280	274	260	250	240	265.66
Speed, m/s		0.606	0.585	0.543	0.543	0.523	0.460	0.543
Speed, km/h	-	2.18	2.10	1.95	1.95	1.88	1.65	1.95
Power output from bullock, kW	-	0.22	0.20	0.19	0.18	0.16	0.14	0.18
Peeling efficiency (%)		94.50	92.00	92.00	90.50	90.24	90.00	91.54
Output (kg/h)		170	165	160	160	155	155	160.83
Fatigue score		13	15	16	17	17	18	16

Table 2 : Performance of Potato Slicer in rotary mode

Parameters	Duration, h							Mean
	In	0.5	1.0	1.5	2	2.5	3.0	
Pulse rate, bpm	50	56	62	70	76	82	86	68.85
Respiration rate, bpm	14	20	28	32	42	46	48	32.85
Body temp, ^{0}C	37.3	37.6	37.9	38.1	38.3	38.5	38.7	38.05
Amb Temp., ^{0}C	25	28	32	34	35.5	39	40	33.35
Rh, %	38	36	32	28	26	24	22	29.42
Draft, kg	-	34	32	30	29	24	24	28.83
Percentage body weight	-	7.55	7.11	6.66	6.44	5.33	5.33	6.40
Draft, N	-	333.54	313.92	294.3	284.49	235.44	235.44	282.85
RPM of bullocks/0.5h	-	62	60	54	52	50	48	54.33
RPM at slicer shaft	-	320	310	300	290	280	280	296.66
Speed, m/s		0.64	0.62	0.56	0.54	0.52	0.50	0.56
Speed, km/h	-	2.33	2.25	2.03	1.95	1.88	1.80	2.04
Power output from bullock, kW	-	0.21	0.19	0.16	0.15	0.12	0.11	0.16
Output (kg/h)		80	76	74	70	70	68	73
Fatigue score		11	13	14	15	17	17	14.5

rate, 48 bpm respiration rate and 38.7 ^{0}C body temperature of the bullocks registering an increase of 72 %, 242 % and 3.75 %, respectively at the end of operation in case of slicer. Increase in pulse rate is attributed to increased metabolism to provide more energy to muscles, increased respiration is the higher need of oxygen rich blood for the work and increase in body temperature is a reflection of heat production due to muscle contraction during the work. The results of this study are similar to the report of Yadav (2001) who had reported significant (P = 0.01) increase in pulse rate, respiration rate and rectal temperature in Hariana bullocks for three hours post exercise. But the values for the present study were lower than the pulse rate (97 bpm), respiration rate (62 bpm) and temperature (103 ^{0}F) as reported by them. This may be due to the difference in breed and the nature of operation. The physiological parameters obtained in the study for both peeler and slicers were below the threshold level of fatigue (Upadhyay and Madan, 1985).

Draft requirements:

There was steady decline in the draft force produced by the bullocks from 372 N and 333 N at the beginning of the operation to 313 N and 235 N at the end for peeler and slicer, respectively. The draft force was more at the start of the work due to higher initial torque and then reduced with the decrease of torque of the rotary system. The mean draft forces were 340 N and 282 N in case of peeler and slicer, respectively which were 7.55 % and 6.22 % equivalent to the combined body weight of the pair of bullocks. The draft requirements in both peeler and slicer were low and small size bullocks could easily operate the machines without being fatigue even after 3 hours of work. The draft load in the present case was sustainable and was in accordance with report of Behera *et al*. (2006) who had observed that bullocks could sustain the draft load of 10 %, 12 % and 14 % of their body weight in summer, rainy and winter seasons, respectively.

RPM of bullocks:

There was steady decline in the revolution of bullocks per 30 minutes from 58 and 62 at the beginning of the operation to 44 and 48 at the end in case of peeler and slicer, respectively. The mean revolutions per 30 minutes for peeler and slicer were 52 and 54, respectively. The increase in rpm was due to decrease in draft force from beginning to the end.

Bullock speed:

There was steady decline in the bullock speed from 2.18 km/h and 2.33 km/h at the beginning of the operation to 1.65 km/h and 1.80 km/h at the end in case of peeler and slicer, respectively. The mean values for peeler and slicer were 1.95 km/h and 2.04 km/h, respectively. It is one of the major parameters that affect the energy output of draft animal. In the present study, the magnitude of reduction in case of peeler and slicer was 24 % and 22 %, respectively indicating that the operation was not much exhaustive for the small size of bullocks.

Power output:

There was steady decline of power output from 0.22 kW and 0.21 kW at the beginning of the operation to 0.14 kW and 0.11 kW at the end in case of peeler and slicer, respectively. The mean values for peeler and slicer were 0.18 kW and 0.16 kW, respectively. The power requirement for operating slicer was less than the peeler. The results for both the machines showed that small size bullock could easily operate the commercially available potato peeler and slicer for 3 hours of work with the suitable work rest cycle.

Shaft rpm of machines:

The rpm of the shafts of peeler and slicer declined from 290 and 320 at the beginning of the experiment to 240 and 280 at the end, respectively. The mean values for peeler and slicer were correspondingly 265 rpm and 296 rpm. In the beginning, the revolution per minute of bullock was more, resulting in the highest rpm and subsequently decreased with the increase in the time of operation due to exhaustion of work.

Peeling efficiency:

The peeling efficiency decreased from 94 % at the beginning of the operation to 90 % at the end. The mean value was 92 %. This may be due to the non-uniform speeds of the bullocks at the time of working with the machine unlike electric motor operated machine. The speed could not be maintained uniformly and was found to be irregular for increased exhaustion in the course of operating the machine. The average capacity of peeler and slicer was found to be 160 kg/h and 73 kg/h in case of peeler and slicer, respectively. However the quantity of potato in manual peeling and slicing with the help of a knife was only 7 kg/h.

Fatigue score:

The bullocks could sustain three hours of potato peeling and then slicing continuously with the suitable work rest cycles followed in the study without getting fatigue as the average fatigue scores were calculated to be only 16 and 14.5 in case of peeling and slicing, respectively and were less than the threshold fatigue score of 20. Fatigue is caused due to accumulation of lactic acid in muscles during work. The findings are similar to the report of Ghosal *et al*. (2012) on the fatigue score of medium size bullocks of Odisha used for cutting straw in chaff cutter.

Table 3 : Cost economics of potato peeling and slicing in rotary mode of operation

Machine	Fixed cost, Rs/h	Variable cost, Rs/h	Total cost, Rs./h	Total cost, Rs/q
Rotary unit	4.60	1.56	6.16	-
Bullock pair	4.04	5.00	9.04	
Man-hr	-	25.00	25.00	
One pair Bullock +one operator	4.04	30.00	34.04	
Potato peeler	7.37	2.5	9.87	
Potato peeling in rotary mode (one bullock operator and one laborer)	4.60 +4.04 + 7.37 = 16.01	1.56 + 30.00 + 2.5 + 25.00 = 59.06	75.07	46.91
Potato peeler with 1 hp motor	11.36	3.85 + 4.00 (electric charge)	19.21	
Potato peeling in 1 hp motor	11.36	3.85+ 4.00 + 25.00(one laborer) = 32.85	44.21	22.10
Potato slicer	6.45	2.18	8.63	
Potato slicing in rotary mode (one bullock operator and one laborer)	4.60 +4.04 + 6.45 = 15.09	1.56 + 30.00 + 2.18 + 25.00 = 58.74	73.83	101.13
Potato slicer with 1 hp motor	10.44	3.54 + 4.00 (electric charge)	17.98	
Potato slicing in 1 hp motor	10.44	3.54+ 4.00 + 25.00 (one laborer) = 32.54	42.98	42.98

Cost economics :

The cost economics of potato peeling and slicing in rotary mode of operation through potato peeler and slicer is presented in Table 3. The potato peeling (Rs. 46/q) and slicing (Rs. 101/q) in rotary mode were not economical compared to the same units when operated by electric motor (Rs. 22/q) and (Rs. 42/q), respectively. The above economics suggests that rotary unit is not economical compared to potato peeling and slicing by electric power but by adopting rotary unit through bullock power, the annual utilization hours of bullocks can be enhanced during their idle period. It will also save the cost of maintenance of bullocks. The payback period of the units can also be decreased if they are used on community basis. The above operations through rotary mode were also found to be well within the draftability of the small size of bullocks of Odisha.

Conclusion :

The operations like potato peeling and slicing can be performed effectively by using potato peeler and slicer in rotary mode by using bullock power to enhance the annual utilization hours of bullocks. The mean draft requirement of the potato peeler and slicer was found to be 7.70 % and 6.40 %, respectively in terms of percentage of body weight of the small size bullock. The bullocks could sustain the draft of both peeler and slicer for 3.0 hours with a work rest cycle of 1hour work + 20 minutes rest + 1 hour work +30 minutes rest + 1 hour work. The output of potato peeler and slicer in rotary mode was observed to be 160 kg/h and 73 kg/h, respectively as against their corresponding values 200 kg/h and 100 kg/h in electrically operated motor and only 7 kg/h in manual peeling and slicing with the help of a knife. The operation of potato peeler and slicer through rotary mode was not economical compared to be operated with electric motor, but it was a meaningful utilization of animal power during the idle period in farm operation to take care of the maintenance cost of bullocks throughout the year by the bullock-owning farmers. The farmers can rely on this system for value addition of potato for chips making in the remote areas without depending upon the electrical energy supplied scantily by the grid.

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