REFINEMENT OF MANUALLY OPERATED CHAFF CUTTER AS PER ERGONOMIC CONSIDERATION

M.Tech. (Agril. Engg.) Thesis

by

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REFINEMENT OF MANUALLY OPERATED CHAFF CUTTER AS PER ERGONOMIC CONSIDERATION

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Madhuri Yadaw

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CERTIFICATE - I

This is to certify that the thesis entitled **"Refinement of manually operated chaff cutter as per ergonomic consideration"** submitted in partial fulfillment of the requirements for the degree of **Master of Technology in Agricultural Engineering** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Madhuri Yadaw** under my guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

Chairman

Date: 13/8/15

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	(Er. M. Quasim)	____________
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Member	(Dr. A.K. Pali)	____________

CERTIFICATE – II

This is to certify that the thesis entitled **"Refinement of manually operated chaff cutter as per ergonomic consideration"** submitted by **Madhuri Yadaw** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Technology in Agricultural Engineering** in the Department of **Farm Machinery and Power Engineering** has been approved by the external examiner and Student's Advisory Committee after oral examination.

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Place : Raipur

Date : 13/8/15

Madhuri

(Madhuri Yadaw)

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%	Per cent
&	And
<	Less then
°C	Degree Centigrade
Cm	Centimeter
Avg.	Average
Beats/min	Beats per minute
Db	Dry basis
dia.	Diameter
eq^n.	Equation
G	Gram
H	Hour
i.e.	That is
Kg	Kilogram
kg/h	Kilogram per hour
kJ/min	Kilo jule per minute
LH	Left Hand
l/min	Litre per minute
M	Meter
Mg	Milligram
Mm	Millimeter
min.	Minute
m^2	Square meter
RH	Right Hand
RPM	Revolution per minute
t/ha	Tons per hectare
viz.	Namely
Wb	Wet basis
wt.	Weight

LIST OF ABBREVIATIONS

Agril. Engg.	Agricultural Engineering
C.G.	Chhattisgarh
CV	Coefficient of Variation
Engg.	Engineering
et al.	Et alibi
etc.	Etcetera
FAE	Faculty of Agricultural Engineering
Fig.	Figure
IGKV	Indira Gandhi Krishi Vishwavidyalaya
M.Tech	Master of Technology
MS	Mild Steel
MSL	Mean sea level
SD	Standard Deviation
SVCAET&RS	SV College of Agricultural Engineering and Technology & Research Station

THESIS ABSTRACT

a) Title of Thesis	:	Refinement of manually operated chaff cutter as per ergonomic consideration
b) Full Name of Student	:	Madhuri Yadaw
c) Major Subject	:	Farm Machinery and Power Engineering
d) Name and Address of the Major Advisor	:	Dr. V.M. Victor Assistant Professor, Department of Farm Machinery and Power, Faculty of Agricultural Engineering, IGKV, Raipur
e) Degree to be awarded	:	Master of Technology in Agricultural Engineering

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Date: 13/8/15

ABSTRACT

Manually operated chaff cutter is one of the most common agricultural equipment being used by small and medium farmer for cutting of fodder. Experiments were conducted to modify the manually operated chaff cutter and problems associated with the existing chaff cutter. This study is planned to refine the design of manually operated chaff cutter as per ergonomic consideration and introduction of safety gadgets, which will help in increasing the machine efficiency, reducing the number of accidents, sufferings and drudgery involved during chaffing the fodder and also enhancing the safety of workers. A survey work was conducted to collect anthropometry data of 200 male and female agricultural workers (100 each). The subjects were chosen randomly from five districts viz. Raipur, Raigarh, Janjgir-Champa, Mungeli, and Jagdalpur of Chhattisgarh state, India with their ages varying from 18-55 years. Mean, standard deviation, coefficient of variation and percentile values (5th, 50th, 95th) of the collected anthropometric dimensions were computed. Chaff cutter handle, feeding tray and operating height of chaff cutter has been modified in existing chaff cutter on the basis of anthropometric dimensions of agricultural workers of local region. Diameter of the handle was modified in such a way to improve the grip and comfort while operating. Length of feeding tray was kept 85 cm as per collected dimension of arm length and the same has been covered up to 45 cm from the cutter for safety of the operator and for proper accommodation of the chaff. To cover the flywheel, wire mesh has been selected considering the optimum finger size of the worker. Result show that after modify manually operated chaff cutter, chaff length decreased and recorded data on chaff length were 1.6 cm and 1.4 cm for green and dry fodder respectively. Capacity of the machine increased by 5.2% and 10.5% for green and dry fodder respectively for male workers. Similarly for female workers the increase in capacities more 6.02% and 9.71% for green and dry fodder respectively. Physiological characteristics of 3 female and male workers observed during chaff cutting with existing and modified machine. Average heart rate for female workers were recorded as 114.27 and 109.65 beats/min for green fodder with the existing and modified machine respectively and 111.97 and 112.00 beats/min for chaffing of dry fodder. For male workers average heart rate was found to be 112.20 and 108.83 beats/min during in case of green fodder and 114.69 and 110.50 beats/min during for dry fodder with the existing and modified machine respectively. The oxygen consumption rate of female workers range between 0.62-0.57 l/min for green fodder and 0.64-0.59 l/min for dry fodder with existing and modified chaff cutter respectively. Similarly for male workers, average oxygen consumption rate was found to vary between 0.6 -0.59 l/min for chaffing of green fodder and 0.63- 0.58 l/min for dry fodder with existing and modified machine respectively. Overall this study helped to modify the manually operated chaff cutter as per ergonomic considerations and thus to increase the performance of machine by increasing its capacity and quality of chaff with safety to the operators.

थीसिस सारांश

अ) थीसिस का शीर्षक:	मानव शास्त्रीय आयाम के परिप्रेक्ष्य में मानव चलित चारा कटाई यंत्र में सुधार
ब) छात्रा का नाम:	माधुरी यादव
स) प्रमुख विषय:	कृषि मशीनरी एवं शक्ति अभियांत्रिकीय
द) प्रमुख सलाहकार का नाम व पता	डॉ. वी. एन. विक्टर प्राध्यापक एस. वी.सी.ए.ई.टी. एवं अनुसंधान केन्द्र इ.गा. कृ. विश्वविद्यालय रायपुर
इ) उपाधि से सम्मानित किया जाएगा:	कृषि अभियांत्रिकीय में मास्टर ऑफ टेक्नोलॉजी

छात्रा के हस्ताक्षर

13/8/15

प्रमुख सलाहकार के हस्ताक्षर

दिनांक 13/8/15

विभागाध्यक्ष के हस्ताक्षर

सारांश

चारा काटने का यंत्र एक सर्वसाधारण उपकरण है, जो कि छोटे एवं मध्यम किसानों द्वारा चारा काटने हेतू उपयोग में लाई जाती है। पूर्व से उपयोग में लाई जा रही चारा काटने की मशीन में पाई जाने वाली खामियो को संशोधित करने हेतु प्रयोग किया गया। इस अध्ययन में मानव चलित चारा काटने की यंत्र के डिजाइन को मानव शास्त्रीय आयामों तथा उपयोग दौरान यंत्र चालक की सुरक्षा को ध्यान में रखते हुये संशोधन हेतु आयोजित किया गया। जिसकी सहायता से मशीन की कार्य क्षमता को बढाई जा सके तथा मशीन के उपयोग दौरान होने वाली दुर्घटना, थकान आदि को कम किया जा सके। मानव शरीर के विभिन्न अंगो की माप जानने के लिए 200 व्यक्तियो जिसमें 100 पुरूष तथा 100 महिला कृषको का सर्वेक्षण किया गया। सर्वेक्षण हेतु व्यक्तियो का अध्ययन छत्तीसगढ राज्य के पॉच जिलो रायपुर, रायगढ, जगदलपुर, जॉजगीर चॉपा और मुंगेली से किया गया। इस सर्वेक्षण से प्राप्त आंकडो की मानक विचलन, विविधता और एकत्र मानवशास्त्रीय आयामो की प्रतिशत भूतियो (5वी., 50वी, 95वी.) के गुणांक में गणना किया गया। चारा काटने की मशीन के हत्थे, फीडिंग ट्रे एवं कार्य करने की ऊचॉई को स्थानीय क्षेत्र के कृषि श्रमिको की मानवशास्त्रीय आयामों के आधार पर मशीन के हत्थे पर मजबुत पकड एवं अधिक आराम के लिए हत्थे के व्यास्त में सुधार किया गया। फिडिंग ट्रे की लंबाई 85

सेमी. तथा चालक की सुरक्षा के लिए 45 सेमी. लंबाईं का ढक्कन ट्रे के ऊपर लगाया गया। फ्लाककईं व्हील को कवर करने के लिए 1 सेमी. चौकोर जाली वाले तार की जाली को लगाया गया। यंत्र का आंकलन सूखा एवं हरा चारा को काटने हेतु, दोनो स्थितियो में अर्थात सुधार के पहले व सुधाार के प चात् महिला एवं पुरूश श्रमिको द्वारा पृथक पृथक किया गया।

अध्ययन में पाया गया कि सं ोधन प चात् चारा काटने पर कटे हुये चारे की लंबाईं 1.6 सेमी. तथा 1.4 सेमी. क्रम ः हरे एवं सुखे चारे हेतु पाईं गईं। यंत्र की कार्यं क्षमता सं ोधन प चात् पुरूश श्रमिको द्वारा हरा एवं सुखा चारा हेतु क्रम ः 5.2 % तथा 10.5 % अधिक एवं महिला श्रमिको द्वारा काटने पर 6.02 % एवं 9.71 % क्रम ः हरा एवं सुखा चारा हेतु पाईं गईं। महिलाओ के लिए भाारीरिक आयाम हद्य की दर 114.27 से 109.65 बार प्रति मिनट तथा 111.97 से 112.00 बार प्रति मिनट, इसी प्रकार ऑक्सीजन ग्रहण करने की दर 0.62 से 0.57 ली. प्रति मिनट तथा 0.64 से 0.54 ली. प्रति मिनट हरा और सुखा चारे के लिए दर्जं किया गया। इसी प्रकार पुरूश श्रमिको के लिए औसत हद्य दर 112.20 से 108.83 तथा 114.69 से 110.50 बार प्रति मिनट एवं ऑक्सीजन ग्रहण करने की क्षमता 0.62 से 0.57 तथा 0.64 से 0.59 ली. प्रति मिनट हरा और सुखा चारे के लिए दर्जं किया गया।

बिना सं ोधन एवं सं ोधित यंत्र को भारीरिक आयाम जैसे औसत हद्य की दर 114.27 तथा 109. 65 धडकन प्रति मिनट एवं 111.97 तथा 112.00 धडकन प्रति मिनट क्रम ः हरा तथा सुखा चारे काटने के दौरान दर्जं किया गया। इसी प्रकार से ऑक्सीजन ग्रहण करने की दर 0.62 तथा 0.57 लीटर प्रति मिनट एवं 0. 64 तथा 0.59 लीटर प्रति मिनट हरा और सुखा चारा काटने के लिए क्रम ः बिना सं ोधित एवं सं ोधित के दर्जं किया गया। इसी प्रकार पुरूश श्रमिको के लिए ऑक्सीजन ग्रहण करने की दर क्रम ः 114.69 तथा 110. 50 लीटर प्रति मिनट हरा एवं सुखा चारा हेतु एवं 0.60 तथा 0.56 लीटर प्रति मिनट क्रम ः हरे तथा सुखे चारे की कटाईं हेतु पुनः क्रम ः बिना सं ोधित और यंत्र के लिए दर्जं किया गया।

इस प्रकार यह अध्ययन मानव चलित चारा काटने के यंत्र की क्षमता को बढाने के साथ साथ सुरक्षित तथा आरामदायक बनाने में मद्द करता है।

CHAPTER I
INTRODUCTION

India rank first in the livestock population. According to livestock census, India has livestock population of about 485 million (Anon, 2003). Chhattisgarh has a rich livestock wealth of 14 million animals, as per the 2007 livestock census, of which the maximum of 65 per cent is the cattle population followed by 20 per cent of goat population. Buffalo constitute 11 per cent of the total while pigs and sheep are 3 and 2 per cent respectively of the total population. It is very necessary to have effective utilization of available feed sources. The cutting of crop residue into small pieces before feeding to the cattle increases the consumption and palatability of feed, hence reducing the wastage. Chaff cutter is a machine used for cutting fodder.

The chaff cutter is a simple but indigenous device, used for cutting straw, chaff, hay and other green/dry fodder into small pieces before being mixed together with other forage to feed animals. It provides very uniform length of cut of fodder. By the use of the chaff cutter, animals are therefore induced to consume a much larger proportion of fodder with their food, which not only improves the condition of the stock, but saves time in feeding. The main parts of manually operated chaff cutter are handle, blades, feeding tray, flywheel, and cutter head.

A majority of rural household irrespective of their socio-economic status and having cattle own a chaff cutter, which is usually operated twice daily for chopping the fodder. Family members, including children, perform the operation and the equipment is easily accessible to children for playing. Due to large availability of chaff cutters, the associated problems, particularly injury to the operator, are also numerous. As per the survey of agricultural accidents, the chaff cutter caused maximum accidents and resulted in various kind of injuries viz. permanent loss of upper limbs, fingers, hand and arms, fractures, cut and other multiple injuries. In an epidemiological study, Mohan *et.al.*(2004) showed that in north India children below 14 years of age were involved in 16% of all agricultural injuries. 30% of all the equipment related injuries among children below 14 year old were caused by fodder cutting machines. In children below 4 year, 50% of injuries resulted from these machines.

Ergonomics is also known as man-machine-environment system. The goal of ergonomics is to design workplace to conform to the physiological, psychological and behavioral capabilities of workers. Anthropometry is the technology of measuring various human physical traits, such as body dimensions of workers and their strength. It is an effort to apply such data to equipment and workplace design to enhance the efficiency, safety and comfort of the operator Pheasant (1986) and Reobuck *et.al*. (1975).

Detailed anthropometric survey in India is important as the body dimension of India population varies from region to region (Majumder, 1972). There is much more difference in body dimension between Western and Indian population, as they vary trum region to region. Anthropometric survey of western, northern, central and southern India has been reported by Sen (1964), Gupta (1983), Gite and Yadav (1989), Frenalandez and Uppugondri(1992).

The development of safety gadgets for chaff cutters will help in reducing number of accidents, sufferings and drudgery involved in chaff cutting the fodders and also enhances the safety of workers. The data of male and female subjects may be used for modified chaff cutter for them. Mismatches between human anthropometric dimensions and equipment dimensions are known to be a contributing factor in decreased productivity, discomfort, accidents, biomechanical stresses, fatigue, injuries, and cumulative traumas. Therefore, various researchers have pointed out the importance of using relevant anthropometric data for modification of chaff cutter.

Looking to the importance of the chaff cutter and problems associated with the existing chaff cutter, this study is planned to refine the design of manually operated chaff cutter and introduction of safety gadgets, which will help in reducing the number of accidents, sufferings and drudgery involved in chaff cutting and also enhancing the safety of workers.

The study was taken up with the following objectives

1. To evaluate the existing manually operated chaff cutter from ergonomic and safety point of view.
2. Design modification of chaff cutter to enhance safety and reduce fatigue of workers.
3. To evaluate the modified chaff cutter.

CHAPTER-II
REVIEW OF LITERATURE

Several studies have been carried out for batter performance of chaff cutter, reduction of injuries by adoption of various safety parameters, parts. In this chapter the reviews collected from different sources on various aspects of the present study have been presented as follows

1. Needs of chaff cutting
2. Accident with chaff cutter
3. Ergonomic and anthropometry
4. Postural change during the farm activities
5. Physiological parameters and energy expenditure of farm activities

2.1 Needs of chaff cutting

Bhargrave *et al.* (1988) reported that the un-chopped straw would provide complete choice for the animal to selectively consume more digestible parts and leaving behind the less digestible parts, which consequently leads to substantial feed wastage. In addition the animal might need to spend more energy for chewing the un-chopped straw, than the chopped straw (Chander, 2011).

Dikshit and Birthal (2010) estimated the feed consumption rates for different livestock species by age-group, sex and function at the national level, as well as demand for different types of feed by the year 2020. According to this study, by 2020 India would require a total 526 million tonnes of dry matter, 855 of green fodder and 56 of concentrate feed (comprising 27.4 Mt of cereals, 4.0 Mt of pulses, 20.6 Mt of oilseeds, oilcakes and meals and 3.6 Mt of manufactured feed). In terms of nutrients, this translates into 738 Mt of dry matter, 379 Mt of total digestible nutrients and 32 Mt of digestible crude protein. The estimates of demand for different feeds will help the policymakers of the country in designing trade strategy to maximize benefits from livestock production.

Tiwari and Kumar (2011) studied that fodder chopping is done mainly to save storage space, to aid in curing to make the fodder more palatable, to facilitate uniform mixing of concentrates and also to keep the fodder free form spoiling while in storage. The machines used for chopping fodder are called chaff cutter or ensilage cutter or silo filler.

2.2 Accident with chaff cutter

Rawal (1984) studied that in Punjab, the human factors were associated with agricultural implement injuries in 73 per cent of cases. These included in attentiveness, wearing of loose garments, overwork and physical in capability.

Kumar and Anjali (2004) reported that the chaff cutter caused accidents about 7.8%. The hand tools related injuries (8% of the total accidents) were non-fatal in nature. Due to the lack of technical capability of the local artisans, adhering to safety and design standards is impractical for the implements fabricated in the rural areas. The analysis emphasizes that the effective safety and health management.

Mohan *et al.* (2004) reported that the fodder cutter machines were used every day by farmers and their families in India for preparation of fodder to feed the livestock they own. An epidemiological study done in North India showed that all age groups sustain fodder cutter injuries while operating the machine. A detailed study of injuries and machine characteristics resulted in a safer fodder cutter design. The design changes cost effective and can be incorporated, in both existing and new fodder cutter machines. This paper reported the process of the community based study and the safer design features of fodder-cutter machine.

Kumar *et al.* (2012) conducted a survey in five villages of Ghaziabad district of Uttar Pradesh (a northern state of India) to determine the causal factors responsible for chaff cutter injuries. It was observed that major injuries were caused during children playing with the machine and workers feeding the fodder in to the chute. Based on the survey results and mechanism of injuries, three safety interventions were developed to prevent the injuries. These interventions can be retrofitted on old machines and can be incorporated in new machines as well. Experiments were conducted using different fodder crops to observe difficulty in chaff cutting with the safety interventions. It was observed that incorporation of the interventions had no effect on performance of chaff cutting operation. These were retrofitted on existing machines at different locations and the response was very positive.

2.3 Ergonomic and anthropometry

Murrel (1979) stated that ergonomics is the scientific study of the relationship between man and his working environment. The goal of ergonomics is to design the task so that its demand stays within the capacities of workers. Its object is to increase the efficiency of human activity by removing those features of design which are likely to cause inefficiency or physical disability in the long term and thus to minimise the cost of operation. He further stated that, to achieve maximum efficiency a man machine system must be designed as a whole.

Klamklay and Sangkhapong (1990) collected anthropometric dimensions of Thailand university students. The average age height, and weight of the female subjects was 19.98 ± 1.30 years, 156.90 ± 4.85 cms, and 49.84 ± 7.50 kgs, respectively. The average age, height, and weight of male subjected was 20.80 ± 1.34 years, 169.17 ± 5.60 cms, and 59.65 ± 8.49 kgs, respectively. Body weight and a set of thirty-eight body dimensions were measured. Several dimensions obtained from the lower-southern population appear to be different from the data recently collected from other regions of Thailand. The current Thai population appears to have greater height and weight than the Thai population of the 1980s and 1990s, but still smaller than the adults from the US and Norway in all selected dimensions.

Nussbaum *et al*. (1999) examined maximal forces exerted by the fingers in a variety of couplings to both enhance and supplement available data. This data was used to determine whether strength could be predicted from other strength. Such processes are of utility when designing and evaluating hand tools and human-machine interfaces involving finger intensive tasks, since the integration of finger force capabilities and task requirements are necessary to reduce the risk of injury to the upper limbs. They determined the maximum voluntary force capabilities (strengths) of the hand and fingers in seven different hand couplings. The couplings differed in the number of fingers that were used and the positioning of the fingers. Specific couplings were chosen to reproduce exertions that are common during hand intensive tasks found in many worklpaces (e.g., inserting fasteners and pushing buttons). This research was motivated by the need to enhance existing data for grip and pinch strength, as well as to provide data on single digit strength using the index finger. In addition, the determinations of finer forces capabilities and requirements are an integral part of an effective design process. The prediction of fingers strength from easily obtainable measures provides pertinent and necessary data without the challenges of collecting force data during tasks and potentially disrupting the individual.

Victor *et al.* (1999) surveyed female farm workers from Chhattisgarh region to distinguished constraint related to the ergonomic problems of farm machinery. Nine body dimensions were measured from 300 subjected between the age groups of 18 to 45 year, from the agricultural machinery design point of view. Collected data have been statistically analyzed and maximum variation was found in body weight of subject. It was observed that mean value of weight and stature for female farm worker are 49.33 kg and 150.16 cm respectively. The data collected were compared with the available data of other region within the country as well as with the western data and variation were found. The data collected could be used for design of agricultural machinery to develop ergonomic consciousness for the designer as well as to promote agri – entrepreneurship.

Kar *et al.* (2003) suggested the use of hand anthropometry data which can help in the proper designing of equipment for better efficiency and more human comfort. Eight hand dimensions had been identified which were considered more useful for designing agricultural hand tools. A right and left hand dimension were collected among 200 male and 204 female workers of West Bengal and eastern India. It was noted that there were significant differences ($P<0.001$) in hand measurements between the right and left hands as well as between right and left hands as well as between male and female workers. However, the percentages of differences in the measurements right and left hands was small (0.10 % to 3.49%) than those between the men and women (7.1 % to 11.96 %) percentile value (5^{th}, 50^{th}, 95^{th}) of the anthropometric dimensions were computed separately for men and women. The hand dimensions of the subjects of present study were compared with the farmers of central part of India. Some proportions of hand dimensions were also computed.

Nag *et al.* (2003) studies the hand breadth, circumference and depth and found that they were normally distributed, with some deviation in case of the finger lengths. Hand length was significantly correlated with the fist, wrist and finger circumferences. The fist and wrist circumference, in combination, was better predictors of the hand length. The hand lengths, breadths and depths, including finger joints of Indian women studies were smaller than those of American, British and West India women. The hand circumferences of the Indian women were also smaller than the American women. The handgrip strengths of the present women were much less ($20.36 \pm 3.24\ kg$) were less than those of American, British and west Indian women. Grip strength was found to be significantly correlated with three hand dimensions (6, 18, 48). Grip strength of India women ($20.36 \pm 3.24\ kg$) were less than those of American, British and West India women. The women who are forced to frequently use cutters, strippers, which are not optimally designed to their hand dimensions and strength range, might have higher prevalence of clinical symptoms and disorders of the hand.

Kong Yong-Ku *et al.* (2005) studied maximum grip force on cylindrical aluminum handles to evaluate the relationships between handle diameter (25–50mm diameter handles), perceived comfort, finger and phalange force distribution, and electromyographic efficiency of finger flexor and extensor muscle activity. A force glove system containing 16 thin profile force sensors was developed to measure finger and phalangeal forces on the cylindrical handles. Participants rated the mid-sized handles (30, 35 and 40 mm) as the most comfortable for maximum grip force exertions. Using a polynomial regression the handle diameter that maximized subjective comfort was calculated as a function of the user's hand length. This optimal handle diameter was 19.7% of the user's hand length. Total finger force capability was inversely related with handle diameter. Electromyographic amplitude of the primary flexor and extensor was unaffected by handle diameter, so the efficiency of the muscle electrical activity followed the same relationship with handle diameter as total finger force. Individual finger and phalange force distributions were examined to evaluate their relationship with perceived comfort. A non-uniform finger/phalange force distribution, in which finger force was proportional to finger muscle capabilities, exhibited a stronger correlation with subjective ratings of comfort than a uniform finger/phalange force distribution.

Krishan (2008) comprises 996 adult male Gujjars of north India ranging in age from 18 to 30 years. Five cephalo-facial measurements were taken on each subject following internationally recommended standard methods and techniques. The results indicate that all the cephalo-facial measurements are strongly and positively correlated ($p < 0{,}001$) with stature. The measurements of the cephalic region have strong correlation with stature than those of facial region. The subjects were randomly selected from 16 villages in Siwaliks and its adjoining plains chandigarh city of north India. The findings of the study indicate that the all five cephalofacial measurements are positively and significantly correlatedwith stature. Cephalic dimensions show stronger correlation with stature than those of facial dimensions.

Mandahawi *et al.* (2008) measured hand dimensions of 120 female and 115 male adults from four major cities in Jordan. Comparisons between Jordanians and other populations (Bangladeshi, Nigerians, Vietnamese, Americans, Hong Kong, Hong Kong Chinese, United Kingdom residents, Americans, and Mexicans) are also made, using published data on the latter. The results showed many significant differences between Jordanians and the other populations, but it was difficult to draw broad generalizations. This study has provided new data for hand dimension that may be useful for the design for hand tools and apparel (e.g. gloves) for the Jordanian populations until more information data become available. The data showed that significant differences exist, not only between the genders in Jordan but also between Jordanians and other populations within genders. Practitioners must be aware of the effects of these differences on job performance, health, and safety in the work environment when a hand device that is designed from data from one population or gender is used by other populations or the other gender within the same population.

Chandra *et al.* (2009) surveyed eight hundred and seventy eight male industrial workers for analyzing thirty seven hand anthropometric characteristics of the Haryana state. Minimum, maximum, mean, standard deviation, skewness, coefficient of variation 5^{th}, 50^{th}, and 95^{th}, percentile for each hand anthropometric dimension calculated. The maximum and minimum hand lengths were 170 mm and 202 mm respectively and the counter values for the hand circumference were 225 mm and 244 mm respectively. Coefficient of variation among the thirty seven hand dimensions ranged from 3.32 to 15.12% with 34 of them below 10%.

Agrawal *et al.* (2012) analysed 1027 subjects (566 male and 461female) of five different tribes namely Khasi, Garo, Jaintia, Hajong and Koch from 35 different villages were selected randomly from seven districts. Thirty-four body dimensions useful for agricultural equipment design were selected and measured. The average weight of female workers was found to be about 10.1% lower than the male agricultural workers whereas the average stature of male is nearly 6.9% higher than the female. Analysis of data shows that the mean weight and stature of female agricultural workers (47.7 kg and 150.8cm) is significantly lower than their male counterparts (53.7 kg and 161.4cm). The mean weight and stature of female workers was found to be 89.8 % and 93.1 % of weight and stature of male agricultural workers.

The stature is an important dimension due to its relevancy in determining several other body dimensions. However, the 5^{th} and 95^{th} percentile values of stature for male agricultural workers are found to be 151.6 cm and 170.5cm, respectively which suggest the fact that any design parameter should not exceed the range making it cumbersome for the user.

Onuoha *et al.* (2012) surveyed in order to obtain information on the body dimensions, which may be used in ergonomic design of farm equipment. The sample which include males and females involved in different agricultural activities were randomly selected from the five states of south east geopolitical zone, namely: Anambra, Abia, Ebonyi, Enugu and Imo state. Thirty (30) structural body dimensions necessary for the design of farm equipments/machineries were identified and the survey was conducted on 500 farm workers (300 males and 200 females) within the age limit of 18 to 50 years. Result revealed that the mean stature of South eastern male farm workers was 163.4 ± 5.84 and females was 156.8 ± 5.28. The comparison between male and female data indicated that male agricultural workers are bigger than the females in all body dimensions except waist circumference, hand breadth and hip breadth. The mean values of waist circumference, hand breadth and hip breadth for the male were $83.2 \pm 4.84, 8.2 \pm 0.32$ and32.4 ± 1.84; whereas the value for female were $88.4 \pm 5.08, 8.7 \pm 0.77$ and 37.4 ± 2.43 respectively. The data also showed significant differences among various body dimensions while comparing with other south western states.

Sahu *et al.* (2013) obtained information on the body dimensions, which may be used ergonomic design of farm equipment. In this study difference hand dimensions of right and left hand of 200 female agricultural workers have been collected and it was noted that there were significant differences in hand measurement between left and right hand of agricultural female workers. The 200 female workers were categorized in four different age groups (18-25, 26-35,36-45,46 to above) whose mean, SD, CV, range were computed according to age groups. Percentile values (5^{th}, 25^{th}, 50^{th}, 95^{th}) of the anthropometric dimension were also computed separately for different age groups. The percentage difference in the measurement between right and left hands was small (0.05% to 0.22%).However, it was common practice of workers to use the same hand tools by both sexes.

2.4 Postural change during the farm activities

During the operation by manually operated chaff cutter the problem of workers who rotated the flywheel, continually chaffing in the standing and bending position. Which affect the change of position helps in providing extra force to optimum chaffing as well as creates more facility to the operator. Locking to the above some of review was undergone and presented below.

Vos (1973) noticed that substantial increase in workload in the bending position occurs when the working level is lower than the level of the feet. The work is to be carried out on the ground itself the squatting position seems the most favorable.

Sawkar (1999) revealed that the handling of tools, multiple postures adopted to perform the activity with lots of twists and turns, the forceful torque movements, the stature content involved in holding the posture to perform the activity. Further, the author revealed that, squatting in forward bent posture to harvest the wheat crop was more strenuous than bending in cutting the crop. However, bending was more strenuous than the standing posture in harvesting of jowar crop.

Borah and Kalita (2002) concluded that combination of standing and bending postures were generally used by most of the farm women for performing cutting (89%), threshing (37%), storage (45%) and sun drying of grains (56%) respectively. Squatting and bending postures were adopted for soaking and preparing the seed for sowing (57%) and preparing threshing yard for threshing (74%). Only bending postures were used for uprooting of seedlings (95%) and transplanting (96%). Sitting posture was used for winnowing (92%), sieving (95%) and cleaning (96%) by majority of the farm women for performing the farm activities.

Singh *et al.* (2012) developed setup which had a provision for attaching on-line torque transducer. Variable crank length was provided that could be adjusted as per the farm women (workers). The setup had also a provision for rising up and down to match workers' conditions. Isometric torque was measured at each quadrant positions of handle (0°, 90°, 180° and 270°) at different crank lengths (17.5, 21, 24, 27 and 30 cm). Higher torque was developed by farm women in standing posture as compared to sitting. The crank length up to 27 cm gave better torque at nearly all positions. The lowest torque may be considered for designing the equipment amongst all positions of handle so that human being could easily operate the equipment.

2.5 Physiological parameters and energy expenditure of farm activities

According to Gross *et.al* (1973) feeling of comfort or discomfort results from the use of muscles and skeleton; posture as well as body movements. Comfort is often but not always coordinated with the amount of energy expended. That is less energy expenditure with greater comfort, the more with discomfort.

Grandjean(1973) observed extensive use of heart rate as a measure to know the extent of stress particularly under static conditions. According to him, heart rate within certain limits rises in direct proportion to the energy expenditure.

Ganguly and Datta (1975) obtained a highly satisfactory linear relationship between energy expenditure and peak heart rate in lower extremity amputees and in normal control subjects, during different teat activities. They also suggested an equation for predicting energy cost.

E=0.068, PHR=4.59.

where,

E= Energy expenditure in Kcal/min.

PHR = Peak heart rate in beats/min.

Saha (1976) obtained a highly satisfactory linear relationship between energy expenditure and working heart rate from data of field studies. He also derived a regression equation for predicting energy expenditure of men of 58 kg body weight from working heart rate.

E (Kcal/min.)=0.0695 PHR (beats/min)-4.332.

Nag *et al.* (1980) reported that the average work pulse rate ranged from 180 to 153 beats/min in different agricultural work. However, for a large number of operations cardiac responses were less than 130 beats / min, which was considered as a moderate level of workload of work. Only water lifting and pedal threshing operations required 153.3 and 140.3 beats/min. respectively. The oxygen uptake at the pulse rates of 120, 130, 140, 150 and 160 beats per min correspond to 43, 48, 55, 61 and 74 per cent of maximal oxygen uptake from 120-150 pulse beat /min, the relative load of work increased by about 5-7 percent of maximal oxygen uptake for every increment of 10 pulse beats per minutes.

Further, the authors have reported that by fixing the oxygen uptake, it is also possible to arrive at 120-132 beats/min., representing a moderate level of activity. The total daily energy expenditure of the group of agricultural workers varied from 10.3 to 11.7 MJ of which 53 to 56 per cent of the total energy, i.e. about 5.6 to 6.6 MJ was expended during a working day, while the time weighted average of the whole day activities amounts to 7.2 to 8.1 kg/min. (i.e. the relative load was only around 20.22 per cent of maximal oxygen uptake), whereas, if the working day energy expenditure only is taken into account, the time weighted average demand was around 10.9 to 14.6 kg/min (i.e. about 30 to 40 percent of maximal oxygen uptake).

Chauhan and Saha (2004) conducted a study on acceptable limits of physiological workload for physically active Indian women. Assuming that Indian women can sustain physical activity for long duration with a Relative Load (RL) 35 per cent without physiological strain and undue fatigue, an attempt has been made to determine the acceptable limits of physiological workload based on the relationship between Energy Expenditure (EE) and RL and between EE and belonging to three different age groups,viz: 21-30, 31-40 and 41-50 years, having body weight ranging from 33 to 55 kg, employed in the job of manual sweeping of railway platform. The acceptable limits of heart beats were worked out to be 110 beats/min, 95 beats/ min and 100 beats/min respectively for different age groups, and the corresponding values of energy expenditure to be 10KJ/min, 9.6KJ/min and 10.5KJ/min, respectively. The difference though not significant, could be attributed to influence of age, body built, and level of physical fitness (VO_2 max), all of which would modify physiological workload.

Mohanty *et al.* (2008) have studied the ergonomic evaluation of pedal paddy thresher revealed that using two operators the physiological responses and physiological cost of work reduced significantly. The HR work, ΔHR, OCR, workload (% of VO_2 max), ERR and physiological cost of work reduced from 135.9 to 121.2 beats/min, 0.91 to 0.79 beats/min, 53.3 to 46.97 %, 18.9 to 16.6 KJ/min and 70 to 56 respectively when two operators were used to operate the thresher instead of one. However, the ΔHR (work pulse) was still higher than the limit of continuous performance (LCP) of 40beats/min. The increase in HR per kg of grain threshed reduced by 48 % contrary to the reduction of HR work by 10.82 %. The pedal force reduced from 232.3 N with single operator to 199.7 N with double operators; a reduction of 14 %. But more pedal force with two operators could increase the number of strokes from 75 to 96/min which resulted in increased peripheral speed of the thresher and the capacity increased from 26.9 to 40.69 kg h-1 person-1; an increase of 51.15 %. It is advisable to operate the thresher with two operators. The pedal force exerted by individual operator was still higher than the mean leg strength of the women operators of eastern India (Orissa and West Bengal). It is suggested that the pedal arm of the thresher should be increased to reduce the pedal force requirement to obtain desired number of strokes per minute. It was further suggested that the feeding height should be increased from 75 cm to 80 cm to prevent bending by the operator while feeding the crop on to the threshing drum.

Kwatra *et al*. (2010) have studied the ergonomic evaluation of paddy threshing activity revealed that the physiological responses and physiological cost of work reduced significantly by using paddy thresher (manually operated). The HR work, ODR, ERR, and physiological cost of work reduced from 154.5 to 122.5 beats/ min, 4.6 a score of 3.7, 17.64 to 12.80 kJ/min and 131 to 52.03 respectively when comparative study was undertaken between manual beating of paddy on drum and the use of paddy thresher (manually operated). The increase in Heart Rate per kg of grain threshed reduced significantly contrary to reduction of ΔHR work by 20.71 percent.

Kumar *et al*. (2010) conducted experiments to determine the human energy expenditure in operating a manual chaff cutter. Three operators of different age groups were selected for the experiments. Calibration was done for all the three operators on bicycle ergo meter and calibration equations were determined. There was increase in energy expenditure with increases in feeding rate. Oxygen consumption was much higher than the sustainable level of 35% VO_2 max for all dry and green fodder. Specific energy increased with increased in diameter of stalk. Specific energy also varied with material and was lower in case of dried material of similar diameter. There was mismatch between the energy expenditure by an operator and the energy requirement for cutting of the crops for sustainable operation.

2.6 Chaff cutter performance

Yadav *et al*. (2010) found that strength parameters play a significant role in design of manually operated push-pull type equipment. Average strength of both hands in standing posture for male and female workers was found to be 209.93 and 117.72 N-m respectively which can be used in the design of manually operated equipment like chaff cutter. Torque strength of preferred hand in sitting posture and hand grip torque worked out in this study for both male and female workers were found very much useful in design of hand controls such as steering, knobs, etc. These strength parameters are found to play a significant role in design/ modification of hand controls and foot controls on different workplaces of machines. The machine workplaces designed on strength parameter data were found to greatly enhance the operator’s comfort, safety and efficiency as well.

Zakiuddin and Modak (2010) developed experimental data based ANN model for human powered fodder chopper. The experimentation was carried on fodder chopper energized by the human power. ANN module was formulated to generate the correct value of output parameters corresponding to various values of the input parameters. The developed ANN can be used to select the best value of various independent features for the designed chaff cutter to match the features of machine by performing the chaff cutting task so as maximize the productivity and minimize the torque and cutting time.

Khope and Modak (2013) conducted a study on design of experimental set-up for establishing empirical relationship for chaff cutter energized by human powered flywheel motor. Accordingly, it was decided to work on chaff cutter with this concept and to establish an empirical relationship for human powered chaff cutting process. Since this was a man-machine system, it is rather difficult and unreliable to adopt total theoretical approach for the development, thus, the experimental approach was adopted. This set up consists of three subsystems namely. (i) Human powered flywheel motor (HPFM) i.e. energy unit. (ii)Torque amplification gears and clutch unit and (iii) process unit i.e. chaff cutter.

CHAPTER - III
METHODS AND MATERIALS

This chapter deals with materials and methodology followed, which include study of existing chaff cutter and modification of chaff cutter as per ergonomic consideration and its evaluation. The various factors which govern the modification of chaff cutter are ergonomic consideration, availability of human power, operational safety, power requirement, cost of operation, availability of spare parts and ease of operation. In this study an effect has been made to kept operation and adjustments quite simple and easy so that farmers can use it without much knowledge.

3.1 Experimental site and climatic condition

The experiment was conducted during 2014-15 in the department of Farm Machinery and Power Engineering at SV College of Agricultural Engineering and Technology & Research Station, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh).

Raipur is situated in the South-Eastern part of Chhattisgarh and lies at 21^{O} 16’ N latitude and 81^{O} 36’ E longitude with an altitude of 298 m above the mean sea level.

Raipur has a tropical wet and dry climate; temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. May is the hottest month when maximum temperature reaches to 41^{O}C and December is the coolest month when minimum temperature reaches 10-15^{O}C. The relative humidity is very low in summer (38-49%) and reaches above 76 percent during monsoon. It has an annual average rainfall of 1200-1600 mm. The maximum value of average monthly rainfall (715.50 mm) in the month of July and minimum value (39.40 mm) were recorded in the months of February. The information was collected from Meteorological Department of College of Agriculture, IGKV, Raipur.

3.2 Anthropometry

Anthropometry, the measurement of human body dimensions and other associated characteristics are very essential for ergonomically designing of any devices or systems to fit the users. It can be more specifically termed as the measurement of human body dimension in static and dynamic conductions, includes measurements of body parts, strength, speed and the ranges of motion across the joints. The anthropometric data are used on a reference data for designing and fabrication of machines and farm equipment so that the machine or farm equipment can suit for all variations of subjects. It built a strong relationship between machine and user and results in high efficiency, user friendliness and safety of the operators, which is very important for human centered design point of view.

3.3 Survey of anthropometry data

A study of randomly selected two hundred (200) agricultural workers (males and females 100 each) of Chhattisgarh states (Raipur, Raigarh, Janjgir-champa, Mungeli and Jagdalpur) was undertaken with their ages ranging from 18 to 55 years. The observation taken carefully to measure all dimension in a correct posture and precise manner. The standard anthropometric definition of measurements and techniques were adopted from Pheasant (1986) and Reobuck et al (1975).

3.4 Body dimensions of agricultural workers

In order to generate anthropometric data of agricultural workers, various body dimensions were measured accurately. Some custom designed and specially developed instruments/equipments are used for this purpose.

All the basic body dimension such as vertical reach Standing height, body weight, shoulder height, eye height, vertical reach, vertical grip reach, shoulder height, elbow height, olecranon height, knee height, span length, waist circumference, wrist circumference, biacromial breadth, bideltoid breadth, arm length etc. were measured in standing posture for that the subject were asked to stand on flat surface. Hand length to measure to the top of the middle finger along the long axis of the hand, palm length is distance from the base of the hand to the furrow where the middle finger folds upon the palm, breadth of palm for the hand measured at the level of the distal end of the metacarpal of the thumb, palm thickness to measure metacarpal phalangeal joint of the middle finger. Diameter of grip is the widest level of a cone which the subject can grasp with his thumb and middle finger touching. Anthropometric measurements were carried out for chaff cutter design/modification. Following anthropometric parameters were selected for this study.

a. Weight

It is measured on a calibrated weighing scale. (Fig. 1-a).

b. Height

It is the vertical distance from standing surface to the top of the head. The subject stands erect and looks straight-forward. (Fig. 1-b).

c. Eye height

The vertical distance from standing surface to the inner corner of the eye. The subject stands erect and looks straight forward. (Fig. 1-c).

d. Acromion (shoulder) height

The vertical distance from standing surface to the acromion. The subject stands erect and looks straight forward. (Fig. 1-d).

e. Elbow height

The vertical distance from standing surface to the top of the radiale. The subject stands erect and looks straight forward. (Fig. 1-e).

f. Olecranon height

The vertical distance from standing surface to the height of the undersurface of the elbow, measured with the arm flexed 90^{o} and the upper arm vertical. The subject stands erect and looks straight forward. (figure 1-f).

g. Vertical reach

The vertical distance from standing surface to the height of middle finger when arm hand and fingers are extended vertically. (Fig. 1-g).

h. Vertical grip reach

The vertical distance from standing surface to the height of pointer held horizontal to the subject's fist when the arm is maximally extended upward. The subject stands erect and looks straight forward.

i. Knee height

The vertical distance from standing surface to the mid point of knee cap. The subject stands erect and looks straight forward. (Fig. 1-h).

j. Span length

The distance between the tips of right and left middle fingers when the subject's arms are maximally extended laterally. (Fig. 1-i).

k. Waist circumference

Circumference of the torso at the waist level. The subject stands erect and looks straight forward. (figure 1-j).

l. Wrist circumference

The circumference of the wrist at the level of the tip of the styloid process of the radius.

m. Biacromial breadth

The transverse distance across the shoulder from right to left acromion. The subject stands erect and looks straight forward. (Fig. 1-k).

n. Bideltoid breadth

The horizontal distance across the maximum lateral protrusion of right and left deltoid muscles. The subject stands erect and looks straight forward. (Fig. 1-l).

o. Hand length

The distance from the base of the hand to the top of the middle finger measured along the long axis of the hand. (Fig. 1-m).

p. Palm length

The distance from the base of the hand to the furrow where the middle finger folds upon the palm.

q. Palm breadth

The breadth of the hand measured at the level of the distal end of the Ist metacarpale of the thumb. (Fig. 1-n).

r. Palm thickness

The thickness of the metacarpal phalangeal joint of the middle finger. (Fig. 1-o).

s. Grip diameter (inside)

The diameter of the widest level of a cone which the subject can grasp with his thumb and middle finger touching. (Fig. 1-p).

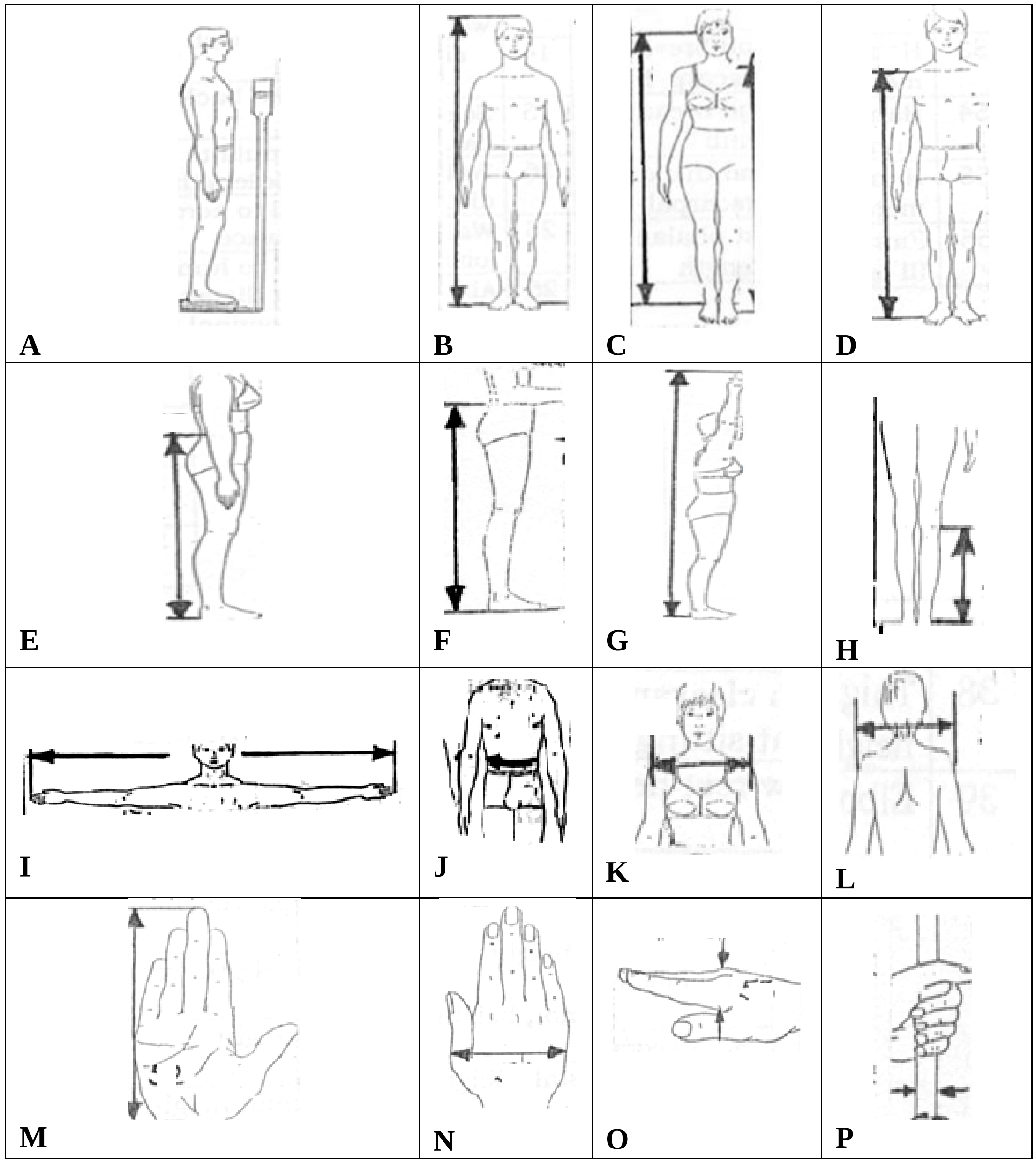
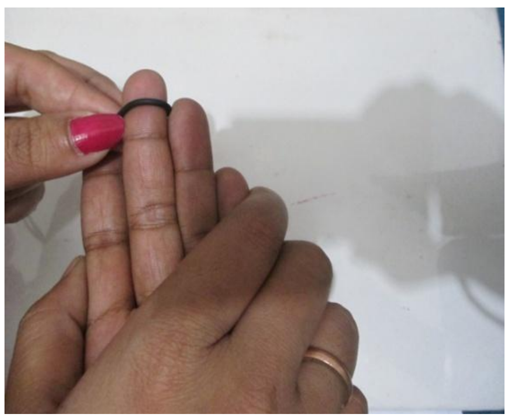


Fig. 3.1 View of measurement of different body dimension

a. Measurement of grip daimeter

b. Stature measurment



c. Fingure circumferance

d. Palm thickness

e. Plam breadth

f. Hand length

Fig. 3.2 Measurement of body dimension

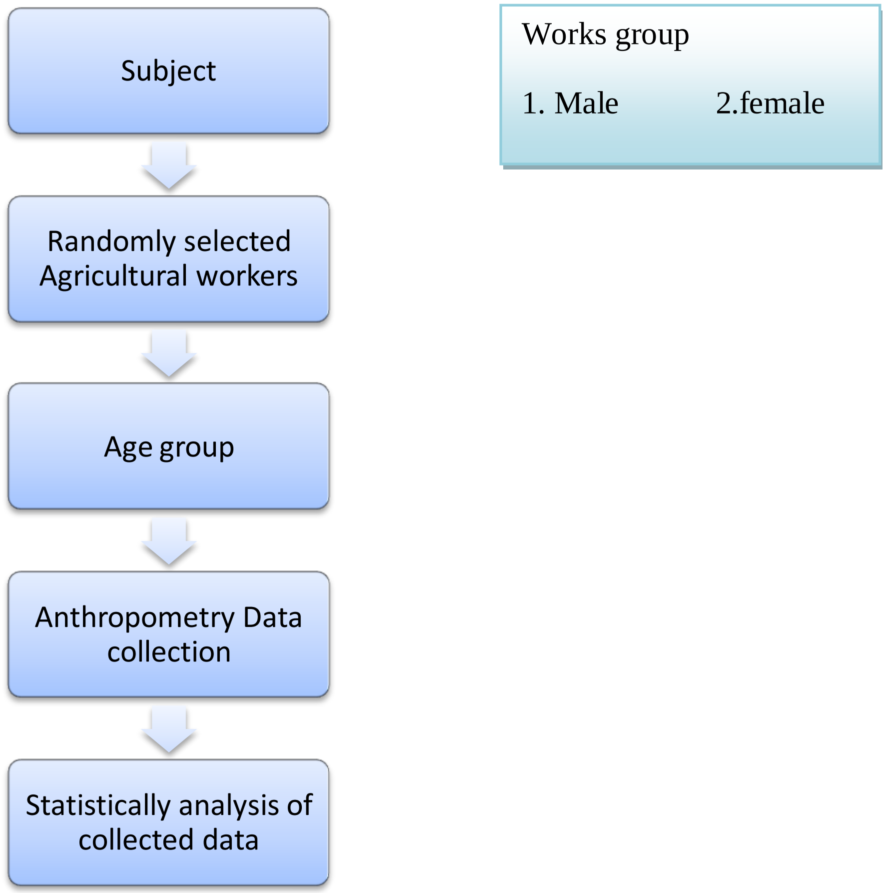


Fig. 3.3 Process flow chart of anthropometrics data survey

3.5 Statistical analysis of anthropometry data

The collected data of anthropometry parameters are statistically analyzed to get sscollect mean, standard deviation, 5^{th} percentile, 50^{th} percentile and 95^{th} percentile was calculated using following formulae for compilations of the data surveyed.

a) A number expressing the central or typical value in a set of data, the mean, which is calculated by dividing the sum of the values in the set by their number.

$$\text{Mean}, X = \sum_{i=1}^{N} x_i$$

Where,

X= mean;

x_i = observations and

N = total number of observations (1, 2…….n).

b) In statistics, the standard deviation (SD, also represented by the Greek letter sigma, σ) for the population standard deviation or for the sample standard deviation) is a measure that is used to quantify the amount of variation or dispersion of a set of data values.

$$\text{Standard Deviation,} \quad \sigma = \sqrt{\frac{\sum(X_i - x)^2}{N}}$$

Where,

X = deviation obtained from actual mean; and

N = total number of observation.

c) The coefficient of variation represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from each other.

$$\text{Coefficient of variation,} \quad CV = \frac{\sigma}{X} \times 100$$

σ = Standard Deviation; and

X= mean.

d) 5^{th} percentile,

$P_5 = 5(n+1)/100$

e) 50^{th} percentile,

$50^{th} = 50(n+1)/100$

f) 95^{th} percentile,

$95^{th} = 95(n+1)/100$

Where,

n = number of observation.

3.6 Existing chaff cutter

The chaff cutter is a simple but indigenous device, for cutting straw chaff, hay and other green fodder into small pieces before being mixed together with other forage and fed to animals. Chaff cutter is one of the most common agricultural machinery being used in rural area. The manually hand operated chaff cutter available in the college was chosen for the study as shown in figure 3.4. The performance of chaff cutter is evaluated and the machine performance as well as physiological performance of operators during working condition were recorded. The detailed technical specification of the chaff cutter is furnished in Table 3.1.

Table 3.1 Specification of existing and modified manually operated chaff cutter:

S. No.	Description	Before modification chaff cutter observations	After modification chaff cutter observations
1	Height of chaff cutter, mm	1400	Adjustable
2	Width of chaff cutter, mm	920	920
3	Length of chaff cutter, mm	1020	1200
4	Number of blades	2	2
5	Diameter of flywheel, mm	580	580
6	Size of throat, mm	227 × 55	227 × 55
7	Recommended clearance b/w fixed and rotating blades, mm	9	9
8	Type of feeding	Manually	Manually
9	Length of feeding tray, mm	675	675
11	Stand height of chaff cutter, mm	750	750
12	Diameter of handle, mm	30	40
13	Length of warning roller	-	225
14	Diameter of warning roller	-	50

Fig. 3.4 Existing and modified chaff cutter

3.7 Design modification of the existing chaff cutter

Modifications were made as per the ergonomic considerations of agricultural workers.

3.7.1 Constructional details

3.7.1.1 Handle

Handle was made of MS rod of 10 mm dia. A wooden hollow grip was provided on this MS handle to increase diameter up to 39 mm. This grip was again covered with plastic pipe with minute clearance between handle and plastic pipe. This clearance enabled operator to rotate the handle easily. Overall, the diameter of handle was 40 mm. The length of handle was kept 500 mm. Diameter of the handle is modified in such a way to improve the grip and comfort while operating. Handle of chaff cutter shown in figure 3.6 (b).

3.7.1.2 Stand

Stand is consisting of main frame and supporting braces. Main frame is made of M.S. angle of size 58 x 58 x 5 mm and M.S. flat of size 40 x 5 mm is used for supporting braces to main frame. Stand can be lowered or lifted upward to adjust the operating height of machine according to worker’s height.

3.7.1.3 Feeding chute

The feeding chute of chaff cutter was kept 85 cm long as per collected anthropometry data of local agricultural workers and 45 cm cover was provided on it for safe operation. This cover helps to save hand and arms from amputation shown in figure 3.6 (c). The caution notice with operational instructions also pricks the mind of operators and thus helps in reduction of accidents.

3.7.1.4 Flywheel cover

Cover on fly wheel and blades as shown in Figure 3.6 (a) help to avoid accidents especially when worker crossing the moving parts. To cover the fly wheel, wire mesh has been selected considering the optimum finger size of the worker. The size of the mesh was taken as 10x 10 mm. To cover the whole fly wheel round shaped wire mesh of size 1060 mm in diameter was used, which was fitted in flywheel with the help of nuts and bolts.

3.7.1.5 Flywheel lock system

Flywheel lock was provided on the machine, to lock the flywheel when not in use as shown in figure 3.6 (d). This arrangement was not present in the existing machine. This lock will use to stop the rotation of fly wheel when not in use.

3.7.1.6. Warning Roller

Warning roller gives warning to operator when hand reached near the cutting blade. Warning roller is providing in the machine at arm reach distance of 80 mm. Warning roller is made up of wooden materials, diameter of roller is 45 mm and length 225 mm. which fixed to the wall of feeding trey with nut and bolt shown in fig 3.6.

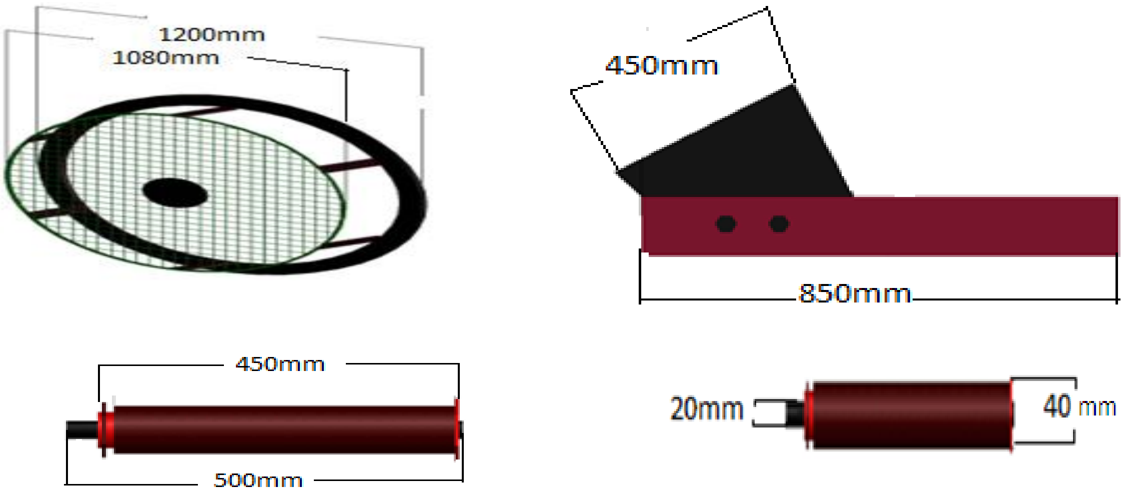


Fig 3.5 Isometric view of various parts - (a) Flywheel cover, (b) Feeding chute, (c) Handle

a. Flywheel cover

b. Handle of chaff cutter

c. Feeding chute

d. Flywheel lock

Fig. 3.6 Components of chaff cutter

3.8 Experimental details

Experiment was conducted to the evaluate the performance the existing chaff cutter and modified chaff cutter for cutting of green fodder (Napier) and dry fodder (paddy straw). The operation was conducted by both male and female farm workers.

3.8.1 Selection of subjects

Three male and three female subjects in the age group of 20 – 50 year were selected. The selected subjects were medically fit and were regular chaff cutter operators. In case of manual chaff cuter two persons required for fodder cutting operation. One person operates the machine and another one was used to feed the fodder. The age, weight and height are given in table 3.2.

Table 3.2 Physical parameters of male and female subject

Subject	Age, year	Weight, kg	Height, cm
MS_1	40	52	158
MS_2	32	50	152
MS_3	45	58	164
WS_4	32	48	158
WS_5	47	55	148
WS_6	52	52	150

3.9 Observation recorded

3.10 Physiological parameter

The physiological parameters of agriculture worker such as heart rate, respiration rate, body temperature, energy expenditure rate and Oxygen consumption rate were recorded at the start of work and after every 10 minutes of work. All the three subject (agricultural workers) were allowed to perform chaff cutting operation on schedules for 10 minutes duration for five times (replication) then the average values for each physiological parameters were calculated for each subject. Observation on physiological were recorded as follows.

3.10.1 Heart rate (beats/min)

The heart rates (beats/min) were recorded before and after chaff cutting operation and was measured by using Stethoscope.

3.10.2 Blood pressure (mm of hg)

The digital B.P apparatus was used to record systolic and diastolic blood pressure as shown in. Figure 3.7.

3.10.3 Oxygen consumption rate (l/min)

The oxygen consumption rate (amount of oxygen consumed by the whole body per unit time) was depended on the heart rate values of the operators the OCR was calculated by using following mathematical formula (Singh *et al*, 2008).

Oxygen consumption rate = $0.0114 \times HR - 0.68$

3.10.4 Energy expenditure rate (kJ/min)

Energy expenditure rate (kJ/min) was computed by using the following equation given by Nag et al. (1979) and Philip (2002).

EER = OCR $\times$ 20.86 kJ/mim

Where, OCR = Oxygen consumption rate (l/mim)

3.10.5 Temperature measurement

The body temperature of the workers was measured by digital thermometer. Body temperatures during cutting of chaff were recorded at the start of work and after every 10 minutes of work.

Fig. 3.7 Physiological parameters were recorded in chaff cutting operation

3.10.6 Machine performance

Sufficient quantity of fodder was piled near the feeding tray and was fed to the machine for a predetermined time. The starting and stopping time was recorded carefully. The starting time was noted when the fodder comes in contact with feed rolls. The material capacity was calculated in terms of kg/h. (IS 7897-1975)

$$\mathrm{Wc} = \frac{\mathrm{W4}\ (100 - \mathrm{M})}{100} \times \frac{20}{\mathrm{L}}$$

Where,

W_c = corrected material capacity of chaff cutter, kg/h;

W_4 = material capacity of chaff cutter at site, kg/h;

M = observed moisture percent; and

L = measured average length of cut in mm.

3.11 Fodder observations

3.11.1 Use fodder for chaffing

In chaff cutter experiment use fodder are green fodder (Napier) and dry fodder (Paddy straw) that fodder are locally available.

3.11.2 Moisture content of chaff

For determining the moisture content of green and dry fodder samples weighting 20 g and 50 g respectively were taken. The moisture content was determined by oven dry method by heating the sample at 70 °C for 24 hours. The weighing of samples was done with the help weighing balance having a least count of 0.1 gm. The moisture content of green and dry fodder on wet basis was determined by using following formula.

$$\text{Moisture content \%} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100$$

3.11.3 Quality of length of cut of fodder

After the completion of test the cut pieces of chaff were measured with the help of caliper. Theoretical length of cut was determined from size and speed of feed rollers, rpm of flywheel and number of blades at two settings of length of cut. Measurement of theoretical length (TLOC) of cut and coefficient of variation was calculated at theoretical and at mean value of actual length of cut by following relationship.

$$\text{TLOC} = \frac{\pi\,(\text{D1} \times \text{N1} + \text{D2} \times \text{N2})/\text{Z}}{\text{N} \times \text{K}}$$

Where,

D1 and D2 are the diameter of upper and lower feed rolls in mm

N1 and N2 are speeds of upper and lower feed rolls in rpm

N = Cutter head speed in rpm

K = Number of knives on the cutter head *i.e.*, 2 for hand chaff cutter

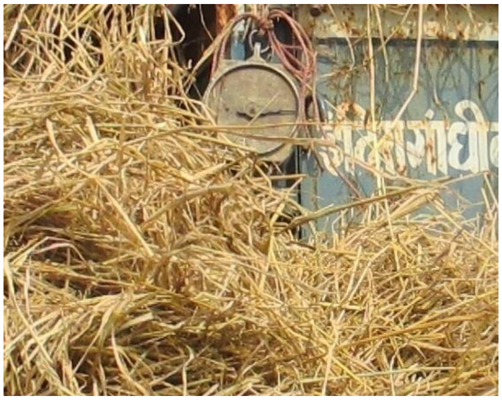
Z = Number of feed rolls

$$\text{Coefficient of variation (CV), \%} = \frac{\sigma}{X} \times 100$$

Where;

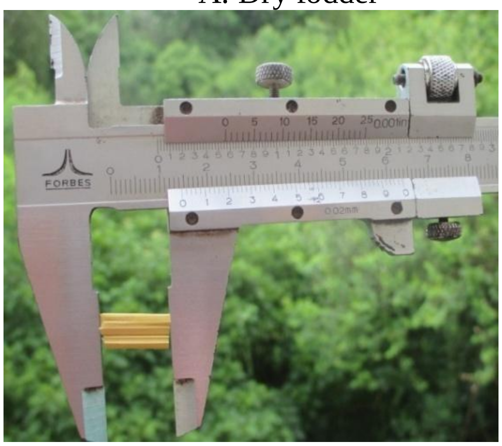
σ = Standard deviation at theoretical length of cut or/mean length of cut; and

X = theoretical length of cut or/mean length of cut based upon 20 samples.



A: Dry fodder

B: Green fodder



C: Length measurement of chaff

D: Weight of cut chaff

Fig. 3.8 Observations of fodder

3.12 Instrument used in experiment

Equipment and instruments used in this experiment for measurement of different parameters are given in APPENDIX A.

CHAPTER-IV
RESULT AND DISCUSSION

This chapter deals with the result of experiments conducted, to study the physiological responses of agricultural workers during chaff cutting operation. The performance of existing as well as modified chaff cutter has also been presented for both male and female farm workers.

4.1 Anthropometric data of agricultural workers of Chhattisgarh

The collected data of 16 different anthropometric dimensions during survey were analyzed for their mean values, standard deviation, coefficient of variation and percentile distribution for both male and female agricultural workers are summarized in Table 4.1 and 4.2.

The mean and standard deviation of values for male and female worker shows that there is a remarkable difference in anthropometric dimensions of male and female agricultural workers in Chhattisgarh plains. In general, presented data indicate that female farm workers are smaller than the male workers in all body dimensions except waist circumference. Analysis of data show that the mean body weight and stature of female agricultural workers was 52.6 kg and 152.6 cm, which was lower than that of male workers as 54.77 kg and 164.54 cm. The mean weight and stature of female workers were found to be 74.3 % and 92.71% of weight and stature of male agricultural workers. The stature is an important body dimension due to its relevancy in determining several other body dimensions.

Further analysis of data show that mean eye height, vertical reach, vertical grip reach, shoulder height, elbow height, olecranon height, knee height, span, wrist circumference, arm length of female workers was 90%-98% of corresponding body dimensions of male workers, while biacromial breadth, bideltoid breadth of female workers was about 80-88% of the corresponding dimensions of the male workers. However, waist circumference of female workers was 3-4% higher than that of male workers. The difference in some of the body dimensions such as wrist circumference, knee height and olecranon height was only 1-3 % between male and female workers.

Table 4.1 Percentile value of different body dimensions of female workers

S No.	Parameters	Mean	SD	CV	Range	Percentile		
						5^{th}	50^{th}	95^{th}
1	Age, year	40.70	8.63	21.2	21.0- 55	26.95	42.00	54.00
2	Body weight,kg	52.60	8.01	15.6	36.0-64	40.00	52.20	63.00
3	Height,cm	152.6	5.40	3.54	137-168	142.0	153.0	160.0
4	Eye height	144.3	6.05	4.19	129-159	136.0	145.0	156.0
5	Vertical reach	197.4	8.38	4.25	178-222	186.8	197.0	211.4
6	Vertical grip reach	187.5	10.5	5.60	117-213	173.9	188.5	200.1
7	shoulder height	130.0	7.76	5.96	111-169	118.9	130.0	141.0
8	Elbow height	99.30	4.28	4.31	92.0-112	94.00	98.00	106.0
9	Olecranon height	100.0	5.62	5.62	84.0-114	90.00	99.80	108.0
10	Knee height	48.10	4.19	8.71	40.0-56.0	42.00	48.00	54.81
11	Span	162.9	6.01	3.69	143.-179	154.0	163.0	173.0
12	Waist circumference	80.30	4.55	5.66	60.0-88.0	73.90	80.00	87.00
13	Wrist circumference	15.20	1.66	10.9	12.0-18.3	12.00	15.00	17.90
14	Biacromial breadth	33.10	2.29	6.92	28.0-36.9	29.00	34.00	36.00
15	Bideltoid breadth	36.50	2.63	7.33	32.0-47.0	32.00	36.00	39.00
16	Arm length	83.20	3.80	4.56	76.0-90.0	76.86	79.70	81.10

Table 4.2 Percentile value of different body dimensions of male workers

S No.	Parameters	Mean	SD	CV	Range	Percentile		
						5^{th}	50^{th}	95^{th}
1	Age, year	36.35	8.57	23.59	18.0-55	25.00	35.00	51.00
2	Body weight, kg	54.77	6.812	12.43	38.0-72	44.00	55.00	65.10
3	Height, cm	164.54	6.26	3.80	153-179	155.0	164.0	176.0
4	Eye height	152.86	6.59	4.31	139-168	144.0	152.0	165.1
5	Vertical reach	208.33	8.92	4.28	186-225	194.0	207.5	223.0
6	Vertical grip reach	198.14	19.34	9.76	104-220	154.5	200.3	215.5
7	shoulder height	137.96	8.037	5.82	125-176	126.9	138.0	149.7
8	Elbow height	106.98	16.30	15.23	93.0-120	94.00	104.0	117.1
9	Olecranon height	101.40	7.09	6.99	89.0-142	91.19	100.0	112.7
10	Knee height	50.05	5.90	11.78	41.0-910.	44.18	49.00	58.01
11	Span	171.19	7.36	4.30	153-183	161.0	170.0	182.0
12	Waist circumference	77.30	4.190	5.42	69.0-89.0	70.92	77.00	84.00
13	Wrist circumference	16.74	1.516	9.05	14.0-2.01	15.00	17.00	19.00
14	Biacromial breadth	37.47	2.86	7.63	32.0-48.0	33.94	37.00	43.05
15	Bideltoid breadth	45.34	2.48	5.47	45.0-3.04	42.00	46.00	48.10
16	Arm length	82.40	3.80	4.60	76.0-90.0	78.86	81.70	84.30

The values of 5^{th}, 50^{th} and 95^{th} percentile were used for design purpose of any component of machine. For design purpose, either one of the boundary values i.e. 5^{th} and 95^{th} percentile or the mean value i.e. 50^{th} percentile is used depending upon the type of dimensional element. As stature is an important body dimension and 5^{th} and 95^{th} percentile values of stature for male workers are found 155.0 cm and 176.05 cm respectively, it was suggested that for any design parameter it should not exceed this range else making it cumbersome for the user. Likewise, in present study to set the handle height which is fitted in chaff cutter flywheel should be 85% of acromial (shoulder) height for getting maximum force applied by worker while rotating flywheel. For 95^{th} percentile value of acromial height it should be 149.71 cm for male workers, which will take care of the acromial height of 95 per cent of the population. On the other hand, for designing size of flywheel of chaff cutter 5^{th} percentile value of 78.86 cm for male workers will take care of 95 per cent of the population Thus for designing this two components 90 per cent of the population is taken into account. The 10 per cent skipped population outside these boundaries will often not be economical to take into account.

4.2 Hand dimension of agricultural workers

The mean value, standard deviation, coefficient of variation, and percentile value of different anthropometric dimension of right and left hand of male and female agricultural workers are presented in Table 4.3 and 4.4 respectively. Result indicated in table 4.3 that the coefficient of variation of the hand length is 0.2 cm between left hand and right hand. Similarly coefficient of variation of palm length, palm breadth, palm thickness, middle figure circumference, thumb circumference, grip diameter and arm grip length were 2.32, 3.28, 2.19, 0.15, 2.81, 0.04 and 2.29 cm respectively between left and right hand for female workers (Table 4.3). For male workers, result indicated that the coefficient of variation of the hand length is 0.17 cm between left hand and right hand. Similarly coefficient of variation of palm breadth, palm thickness, middle figure circumference, thumb circumference and arm grip length were 0.17, 0.5, 0.12, 0.03, 0.23,0.01 and 0.03 respectively between left and right hand.

Table 4.3 Hand dimension of female workers

PARAMETERS (cm)	MEAN		SD		CV%		PERCENTILE					
							5th		50th		95th	
	RH	LH	RH	LH	RH	LH	RH	LH	RL	LH	RH	LH
Hand length	17.8	17.7	0.80	0.80	4.74	4.53	16.7	16.5	17.8	17.5	19.0	19.0
Palm length .cm	9.90	10.0	0.71	0.71	9.38	7.06	8.70	8.99	9.95	10.0	11.5	11.3
Palm breath cm	8.30	8.70	0.77	0.77	12.16	8.88	6.90	7.20	8.10	8.90	10.0	10.0
Palm thickness cm	2.60	2.70	0.29	0.29	13.04	10.85	2.00	2.10	2.65	2.80	3.00	3.00
Middle Finger Circumference	4.70	4.60	0.33	0.33	7.36	7.21	4.19	4.20	4.70	4.60	5.10	5.00
Thumb Circumference	5.60	5.80	0.34	0.34	8.72	5.91	5.00	5.20	5.60	5.80	6.30	6.30
Grip Diameter	4.40	4.40	0.65	0.65	14.80	14.76	3.00	3.00	4.69	4.69	5.08	5.08
Arm grip length	75.6	80.6	5.58	5.58	9.21	6.92	65.0	68.9	74.2	83.0	84.0	85.0

Table 4.4 Hand dimension of male workers

PARAMETERS (cm)	MEAN		SD		CV%		PERCENTILE					
							5th		50th		95th	
	RH	LH	RH	LH	RH	LH	RH	LH	RL	LH	RH	LH
Hand dimension	18.9	0.80	0.89	4.53	4.92	4.75	17.7	16.5	19.0	19.0	20.3	20.0
Palm length .cm	10.5	0.71	0.68	7.06	5.96	6.46	9.00	8.99	10.7	10.6	11.2	11.2
Palm cm	9.24	0.77	0.74	8.88	7.98	8.10	8.00	7.20	9.30	9.30	10.2	10.2
Palm thickens cm	2.66	0.29	0.32	10.8	12.0	12.1	2.00	2.10	2.60	2.60	3.10	3.10
Middle Finger Circumference	4.08	0.33	0.59	7.21	14.4	14.6	3.00	4.20	4.20	4.20	5.00	5.00
Thumb Circumference	5.36	0.34	0.61	5.91	11.4	11.5	4.29	5.20	5.50	5.50	6.00	6.00
Grip Diameter, cm	3.99	0.65	0.45	14.7	11.3	11.3	3.80	3.80	4.00	4.00	4.90	4.90
Arm grip length cm	74.0	5.58	2.13	6.92	2.85	2.88	70.0	68.9	74.0	74.0	78.0	78.0

In manually operated machineries, proper grip is required and essential for effective force application during operation. In case of manually operated chaff cutter handle is provided in flyw1heel which is used to rotate flywheel of chaff cutter by force application. The 5th, 50th and 95th percentile values of grip diameter were found to be 3.8, 4.0 and 4.8cm for male and 3.0, 4.6 and 4.9. for female farm workers, respectively. The grip dimension of any tool need to be designed in a comfortable way such that person(s) with 5th percentile body dimensions could properly grip the handle. Therefore the minimum diameter of the grip should be 3.8 cm for male and 3.0 cm for female farm workers.

4.3 Machine performance

The existing chaff cutter has been modified on the basis of ergonomic consideration and safety aspects. The existing and modified chaff cutter has been evaluated for chaffing of green and dry fodder. Collected data on machine performance has been presented in Table 4.5 and 4.6.

4.3.1 Length of chaff

The data on length of chaff was recorded during chaffing of green and dry fodder for female and male agricultural worker and average value is given table 4.5. Results indicated that the average length of green fodder was decreased from 13.8 mm to 12.8 mm i.e. the length of chaff was decreased by 1.6 mm after modification of chaff cutter. Similarly during chaffing of dry fodder average length of chaff was decreased from 15.2mm to 13.8mm i.e. the length of chaff decreased by 1.4 mm after modification of chaff cutter. This may be due to the fact that power exerted by the operator to rotate the flywheel of chaff cutter was increased due to the modification as per ergonomic consideration. It was found that the rpm of flywheel was increased from 48 to 56 revaluations per minute of the modification of chaff cutter.

Table 4.5 Length of chaff

Length of green fodder (mm)		Length of dry fodder (mm)	
Before modification	After modification	Before modification	After modification
13.8	12.2	15.2	13.8

4.3.2 Capacity of chaff cutter

The capacity of chaff cutter recorded during chaffing of green and dry fodder by male and female agricultural workers are presented in Table 4.6. Results show that the capacity of chaffing increased by 2.7% and 3.63 % for green and dry fodder respectively after modification and operated by male workers. Similarly chaff cutter capacity increased by 3.94% and 3.89 % for green fodder and dry fodder respectively after modification and operated by female workers. Overall the mean value of capacity of chaff cutter presented in Table 4.6 shows that capacity of machine after modification was increased by 5.6% and 10.5% for green and dry fodder for male workers and female workers for 6.02% and 9.71% for green and dry fodder respectively.

Table 4.6 Capacity of chaff cutter for male workers

Subject	Green fodder(kg/h)		Dry fodder(kg/h)	
	Before modification	After modification	Before modification	After modification
Male	55.25	57.95	45.6	49.25
Female	50.94	54.88	43.5	47.39
Average(kg/h)	53.09	57.41	44.7	48.32
SD	2.160	1.640	1.06	0.930
CV%	0.040	0.030	0.02	0.020

4.4 Physical and Physiological characteristics of subject

The basic physical and physiological characteristics of 3 subject female (FS1, FS2, FS3) and 3(FS1, FS2, FS3) subject male at different age group participated in the experiment for performance evaluation of chaff cutter from ergonomical point of view for agricultural workers.

4.4.1 Heart rate response for female workers (beats/min)

The average heart rate after 10 minutes of chaff cutting operation for green and dry fodder recorded for female and male workers before and after modification of chaff cutter is presented in tables 4.7 and 4.8. The average heart rate (beats/min) for female workers (Table.4.7) was found 114.27 and 109.65 beats/min before and after modification of chaff cutter, to be for green fodder. The heart rate was observed as 115.97 and 112.00 beats/min before and after modification of chaff cutter, respectively for dry fodder. Similarly average heart rates (beats/min) for male workers (table.4.8) were found 112.20 before and 108.83 beats/min after modifications for green fodder. The heart rates were observed 114.96 beats/min before and 110.50 beats/min after modification, respectively for dry fodder.

Table 4.7 Average heart rate (beats/min) obtained for female subject during the operation before and after modification of chaff cutter

Subject	Green fodder		Dry fodder	
	Before modification	After modification	Before modification	After modification
FS1	114.2	108.6	115.3	112.4
FS2	116.4	110.5	118.4	109.2
FS3	112.2	109.7	114.2	114.3
Average	114.2	109.65	115.9	112.0
SD	2.110	0.950	2.180	2.604
CV	1.840	0.870	1.880	2.325

Table 4.8 Average heart rate (beats/min) obtained for male subject during the operation at before and after modification of chaff cutter

Subject	Green fodder		Dry fodder	
	Before	After	Before	After
MS1	112.10	106.40	114.51	111.50
MS2	114.20	111.50	113.22	110.20
MS3	110.30	108.60	116.34	109.80
Average	112.20	108.83	114.69	110.50
SD	1.95	2.56	1.57	0.89
CV	1.74	2.35	1.37	0.80

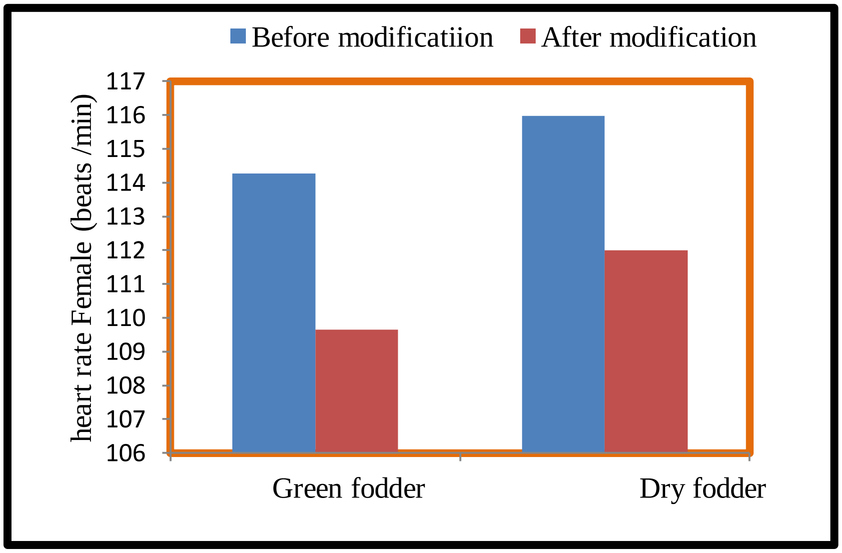


Fig. 4.1 Heart rate (beats/min) obtained for female subject during the operation before and after modification chaff cutter

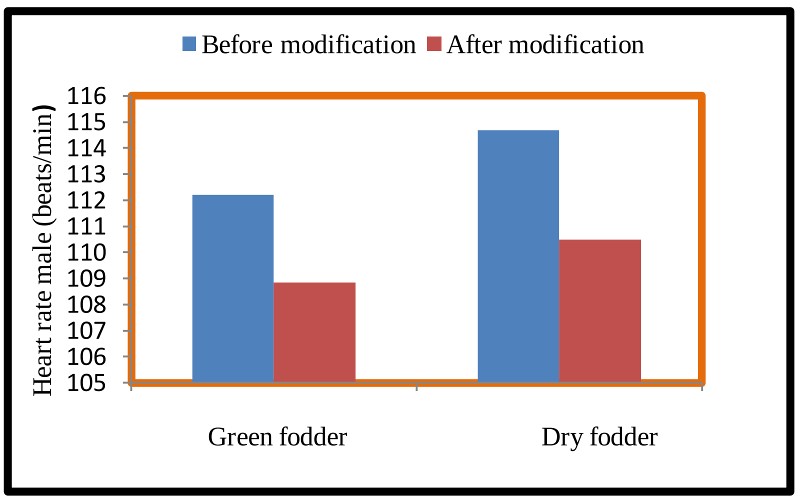


Fig. 4.2 Heart rate (beats/min) obtained for male subject during the operation at before and after modified chaff cutter

4.4.2 Body temperature of female workers during operation (℃)

The body temperature rate after 10 minutes of chaff cutting operation for green and dry fodder recorded for female and male workers before and after modification of chaff cutter is presented in table 4.9 and 4.10. The average body temperature (℃) for female workers (Table.4.9) were found 37.0 and 36.9 before and after modification of chaff cutter, respectively for green fodder. The body temperature was observed 37.2 and 37.1 before and after modification of chaff cutter, respectively for dry fodder. Similarly average body temperature (°C) for male workers (Table.4.10) were found 37.2 before and 37.1 (°C) after modifications for green fodder. The body temperature was observed 37.2 before and 37.1 (°C) after modification, respectively for dry fodder.

Table 4.9 Average body temperature (°C) obtained for female subject during the operation before and after modification of chaff cutter

Subject	Green		Dry	
	Before	After	Before	After
FS1	37.0	36.8	37.2	37.2
FS2	37.1	36.9	37.2	37.1
FS3	36.9	37.1	37.1	37.0
Average	37.0	36.9	37.2	37.1
SD	0.10	0.15	0.05	0.1
CV	0.27	0.41	0.16	0.27

Table 4.10 Average body temperatures (°C) obtained for male subject during the operation before and after modified chaff cutter

Subject	Green fodder		Dry fodder	
	Before	After	Before	After
MS1	37.1	37.1	37.3	37.2
MS2	37.2	37.2	37.2	37.2
MS3	37.2	37.2	37.1	37.1
Average	37.2	37.1	37.2	37.1
SD	0.06	0.06	0.10	0.06
CV	0.16	0.16	0.27	0.16

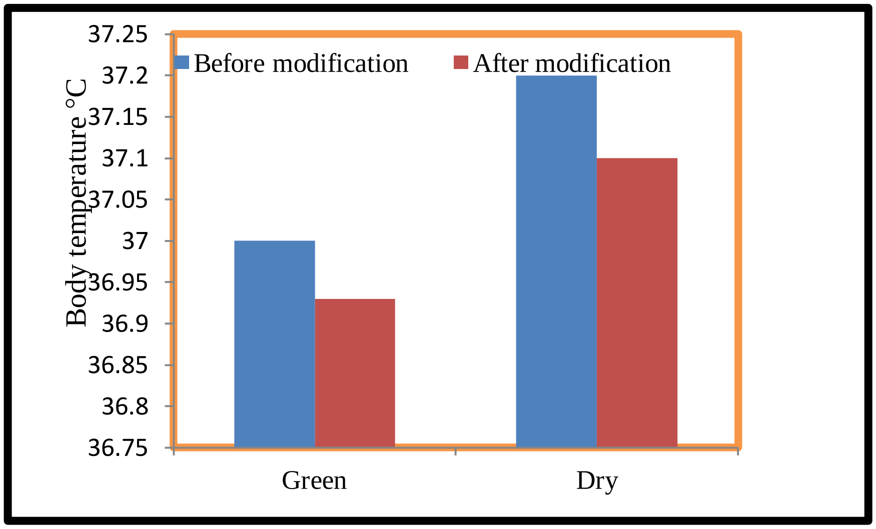


Fig 4.3 Body temperature (°C) obtained for female subject during the operation before and after modification of chaff cutter

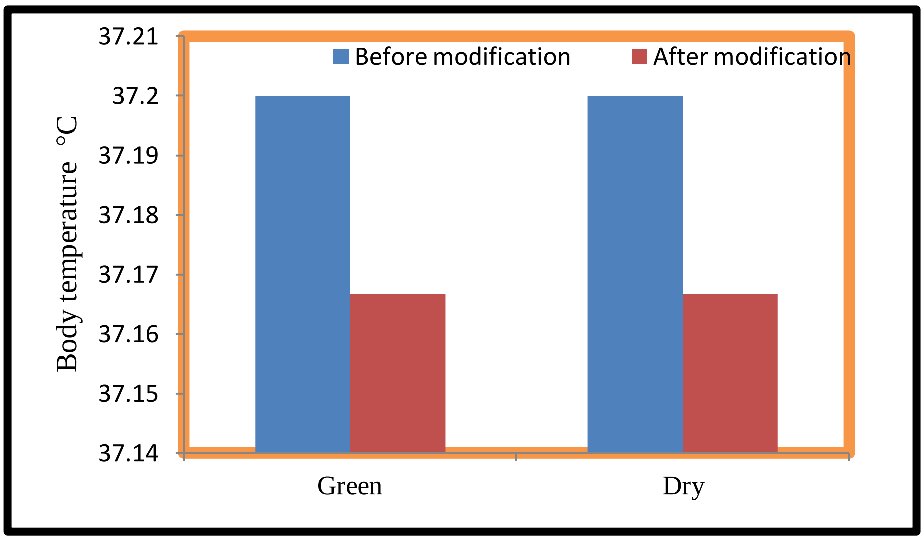


Fig 4.4 Body temperatures (°C) obtained for male subject during the operation before and after modification of chaff cutter

4.4.3 Blood pressure of agricultural workers (mm of Hg)

The average blood pressure after 10 minutes of chaff cutting operation for green and dry fodder recorded for female and male workers before and after modification of chaff cutter is presented in table 4.11 and 4.12. Initial average blood pressure of the subjects i.e, male and female were found in the range of 128 systolic and 85 diastolic and 118 systolic and 81 diastolic respectively.

During chaff cutting of green fodder, the mean systolic and diastolic blood pressure (mm of Hg) for female workers were found 138.07 and 88.40 respectively before modification and 131.77 and 87.50 after modification of chaff cutter while for the male workers the value were found to be 137.0 and 87.13 respectively before modification and 128.87and 87.53 after modification respectively. Similarly during chaffing of dry fodder, the mean systolic and diastolic blood pressure (mm of Hg) for female workers were found 141.13 and 89.20 respectively before modification and 138.20 and 89.87 after modification of chaff cutter while for the male workers the value were found to be 139.47 and 87.73 respectively before modification and 137.27and 88.73 after modification respectively.

Table 4.11 Blood pressures (mm of Hg) obtained for female subject during the operation before and after modification of chaff cutter

Subject	Green				Dry			
	Systolic		Diastolic		Systolic		Diastolic	
	Before	After	Before	After	Before	After	Before	After
FS1	129.4	88.6	88.3	141.1	137.3	90.2	90.1	129.4
FS2	133.6	88.8	87.9	141.5	138.6	89.3	88.6	133.6
FS3	132.3	87.8	86.3	140.8	138.7	90.1	89.3	132.3
Average	131.7	88.40	87.50	141.13	138.20	89.87	89.33	131.77
SD	2.150	0.530	1.060	0.350	0.780	0.490	0.750	2.150
CV	1.630	0.600	1.210	0.250	0.570	0.550	0.840	1.630

Table 4.12 Blood pressure (mm of Hg) obtained for male subject during the operation before and after modification chaff cutter

Subject	Green				Dry			
	Systolic		Diastolic		Systolic		Diastolic	
	Before	After	Before	After	Before	After	Before	After
MS1	136.4	128.4	88.40	88.00	140.0	137.0	90.0	90.0
MS2	136.8	128.8	87.2	87.2	140.2	137.6	89.2	88.0
MS3	137.8	129.4	85.8	87.4	138.2	137.2	90.0	88.2
Average	137	128.8	87.1	87.53	139.4	137.2	89.7	88.7
CV	0.72	0.500	1.30	0.42	1.10	0.31	0.46	1.10
SD	0.53	0.390	1.49	0.48	0.79	0.22	0.51	1.24

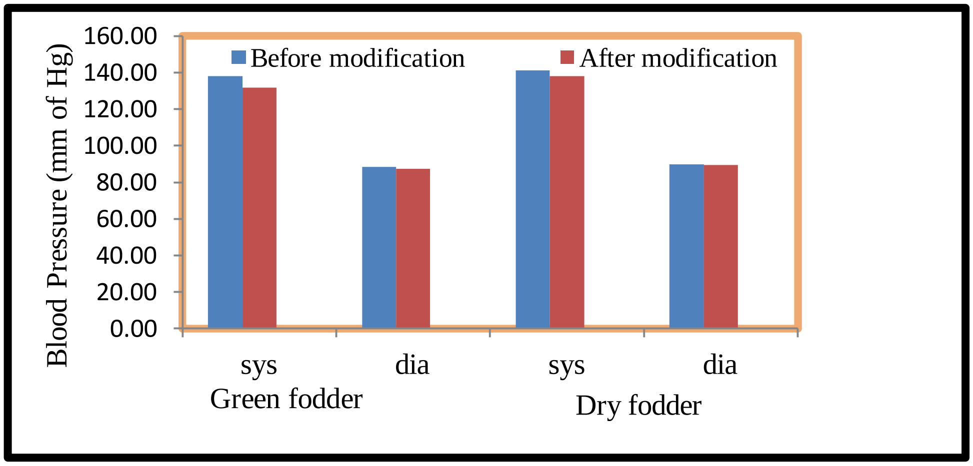


Fig. 4.5 Blood pressures (mm of hg) obtained for female subject during the operation before and after modification chaff cutter

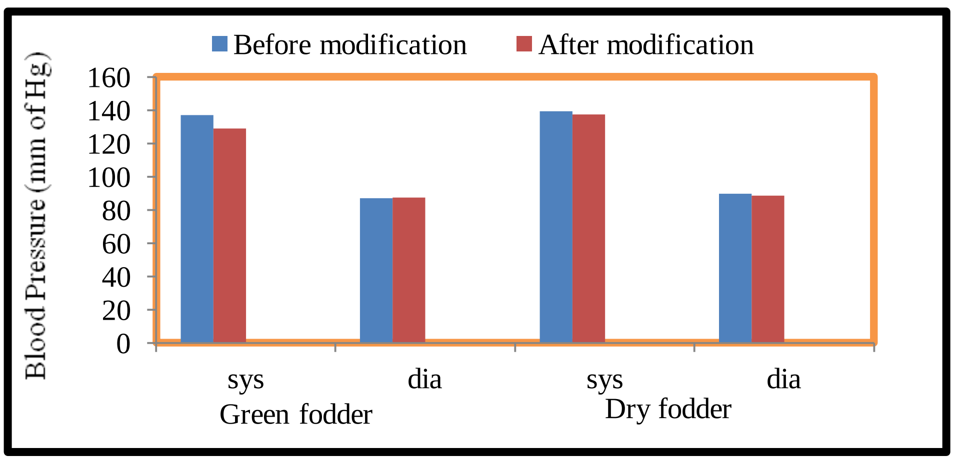


Fig. 4.6 Blood pressure (mm of hg) obtained for male subject during the operation before and after modification of chaff cutter

4.4.4 Oxygen consumption rate (l/min)

The average oxygen consumption rate after 10 minutes of chaff cutting operation for green and dry fodder recorded for female and male workers before and after modification of chaff cutter is presented in table 4.7 and 4.8. The average oxygen consumption rate (l/min) for female workers (table.4.7) were found 0.623 and 0.57 before and after modification of chaff cutter, respectively for green fodder. The oxygen consumption was observed 0.64 and 0.597 before and after modification of chaff cutter respectively for dry fodder. Similarly average oxygen consumption rates (l/min) for male workers (table.4.8) were found 0.60 before and 0.56 after modifications for green fodder. The average consumption rates were observed 0.63 before and 0.58 after modification respectively for dry fodder.

Table 4.13 Oxygen consumption rate (l/min) obtained for female subject during the operation before and after modified chaff cutter

Subject	Green		Dry	
	Before	After	Before	After
FS1	0.62	0.56	0.63	0.60
FS2	0.65	0.58	0.67	0.56
FS3	0.60	0.57	0.62	0.62
Average	0.623	0.570	0.642	0.597
SD	0.024	0.011	0.025	0.030
CV	3.855	1.903	3.869	4.976

Table 4.14 Oxygen consumption rate (l/min) obtained for male subject during the operation before and after modified chaff cutter

Subject	Green		Dry	
	Before	After	Before	After
MS1	0.60	0.53	0.63	0.59
MS2	0.62	0.59	0.61	0.58
MS3	0.58	0.56	0.65	0.57
Average	0.60	0.56	0.63	0.58
SD	0.02	0.03	0.02	0.01
CV	3.71	5.20	2.85	1.75

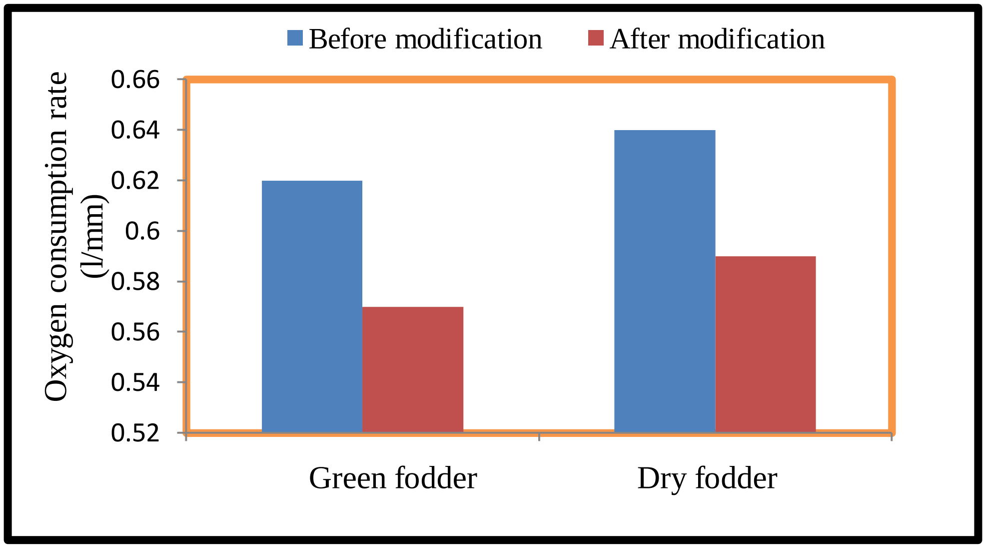


Fig 4.7 Oxygen consumption rate (l/min) obtained for female subject during the operation before and after modification of chaff cutter

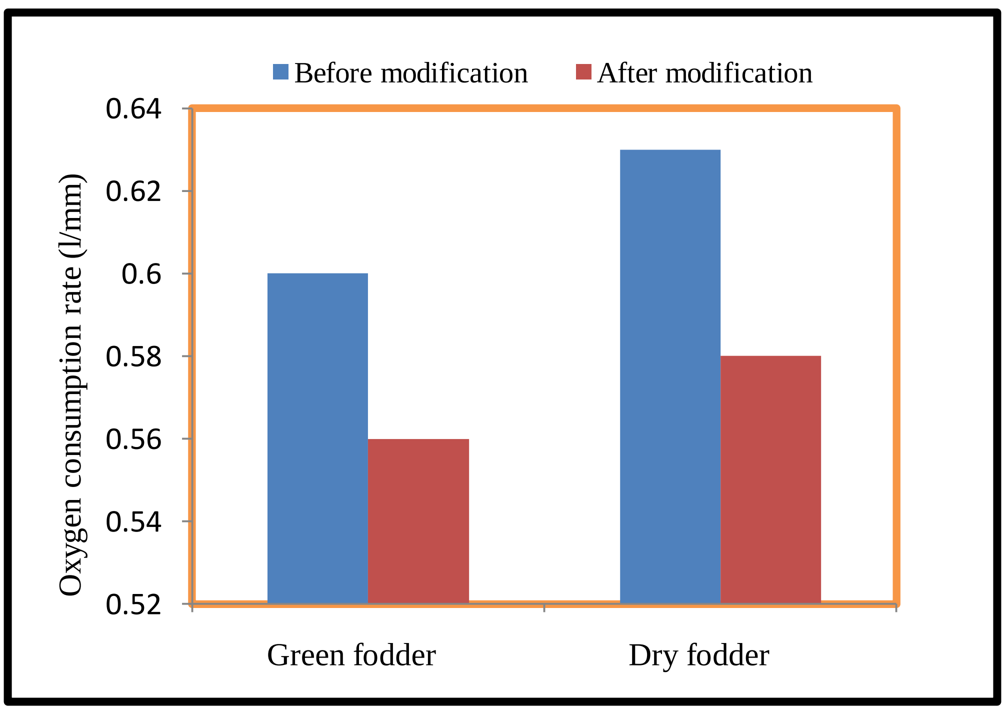


Fig 4.8 Oxygen consumption rate (l/min) obtained for male subject during the operation before and after modified chaff cutter

4.4.5 Energy expenditure rate (kJ/min)

The energy expenditure rate after 10 minutes of chaff cutting operation for green and dry fodder recorded for female and male workers before and after modification of chaff cutter is presented in Table 4.7 and 4.8. The average energy expenditure rate (kJ/min) for female workers (Table.4.7) were found 13 and 11.89 before and after modification of chaff cutter, respectively for green fodder. The energy expenditure rate was observed 13.37 and 12.35 before and after modification of chaff cutter, respectively for dry fodder. Similarly average oxygen consumption rates (kJ/min) for male workers (Table.4.8) were found 12.51 before and 11.68 after modifications for green fodder. The oxygen consumption rates were observed 13.14 before and 12.09(Kj/min) after modification, respectively for dry fodder.

Table 4.15 Average energy expenditure rate (kJ/min) obtained for female subject during the operation before and after modification of chaff cutter

Subject	Green		Dry	
	Before	After	Before	After
FS1	12.93	11.68	13.14	12.51
FS2	13.56	12.09	13.97	11.68
FS3	12.51	11.89	13.35	12.37
Average	13.00	11.89	13.35	0.640
SD	0.530	0.210	0.550	0.640
CV	4.070	1.720	4.120	5.140

Table 4.16 Energy expenditure rate (kJ/min) obtained for male subject during the operation before and after modification of chaff cutter

Subject	Green		Dry	
	Before	After	Before	After
MS1	12.51	11.05	13.14	12.3
MS2	12.93	12.3	12.72	12.09
MS3	12.09	11.68	13.55	11.89
Average	12.51	11.68	13.14	12.09
SD	0.420	0.630	0.420	0.210
CV	3.360	5.350	3.160	1.700

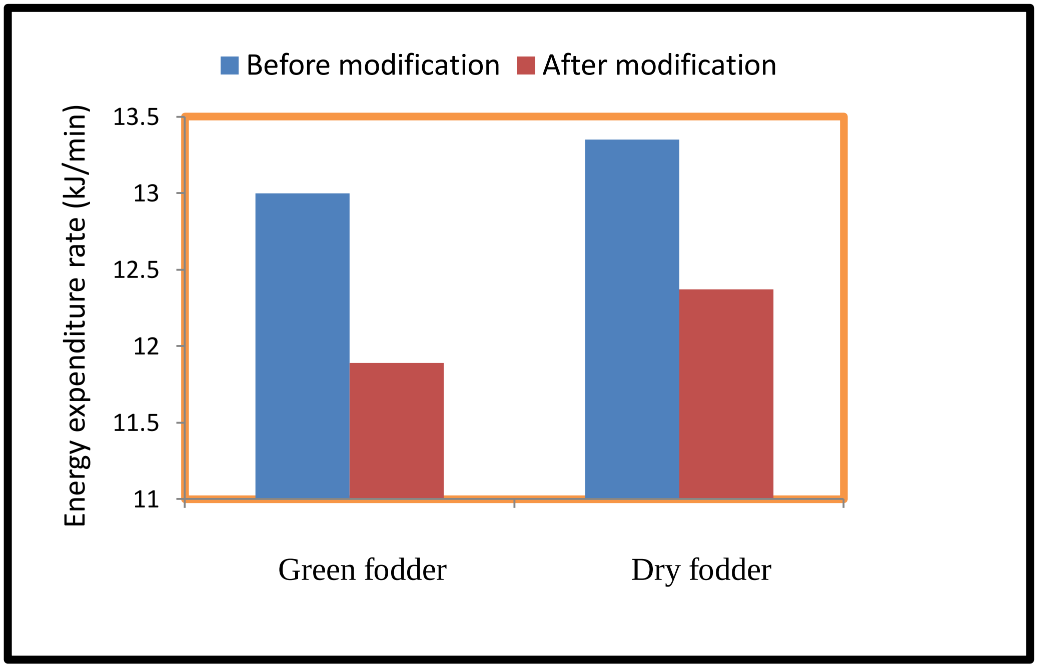


Fig 4.9 Energy expenditure rate (kJ/min) obtained for female subject during the operation before and after modification of chaff cutter

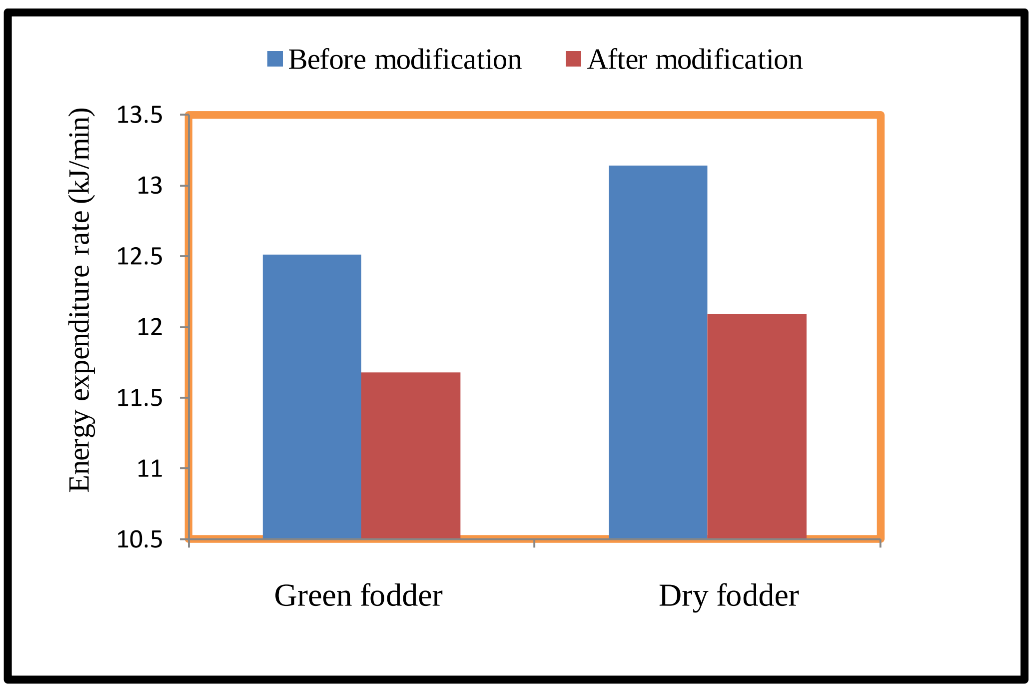


Fig 4.10 Energy expenditure rate (kJ/min) obtained for male subject during the operation before and after modification of chaff cutter

CHAPTER-V
SUMMARY AND CONCLUSION

Modification of manually operated chaff cutter machine with a view to improve efficiency and reduce the injuries to the operator. The machine was modified considering the ergonomic considerations for human comfort and safety. Physiological parameters of workers have been also considered before and after operating chaff cutter for evaluation of the machine.

The machine consisted of handle, blades, feeding tray, flywheel, and cutter head. Some of the machine parts is redesigned considering the anthropometry data of randomly selected workers in five districts ie., Raipur, Raigarh, Jagdalpur, Mungeli, Janjgir-Chanpa, Survey was conducted for measuring the anthropometry dimensions of agricultural workers (i.e., male and female, 100 each) and mean, standard deviation, coefficient of variation, and percentile values (5^{th}, 50^{th}, 95^{th}) of the collected anthropometric dimensions were also computed. Chaff Cutter handle, feeding tray, fly wheel cover and stand has been modified. Diameter of the handle was kept 40 mm to improve the grip and comfort while operating the handle. Feeding tray has been covered up to 450 mm from the cutter for safety of the operator and also the length of the tray was increased to 850 mm to accommodate the chaff and safety purpose. To cover the fly wheel, mesh has been selected considering the optimum finger size of the worker. The size of the mesh was taken 10x 10 mm. The existing stand was replaced with an adjustable stand according to collected body dimensions of the agricultural workers for comfortable operation of the machine. As per the design modification the machine was fabricated in the workshop of FAE, I.G.K.V.Raipur. The machine was tested for performance in three different age group of male and female workers for chaffing of dry and green fodder. For evaluatrion of the existing and modified machines, physiological parameters were also considered during chaffing operation for both male and female farm workers. This study has been planned which particularly concentrates on the agricultural workers of Chhattisgarh region with following objectives.

1. To evaluate existing manually operated chaff cutter from ergonomic and safety point of view.
2. Design modification of chaff cutter to enhance safety and reduce fatigue of workers.
3. To evaluate the modified chaff cutter.

On the basis of study conducted on refinement of chaff cutter as per ergonomic considerations obtained findings were given below:

1. Analysis of data show that the mean body weight (52.6 kg) and stature (152.6 cm) of female agricultural workers than body weight of (54.77 kg) and stature (164.54 cm) of male farm workers.
2. The difference in some of the body dimensions such as wrist circumference, knee height and olecranon height etc was only 1-3 % between male and female workers.
3. After modification it was observed that the chaff length decreases from 13.8mm to 12.2mm for green fodder and 15.2mm to 13.8mm for dry fodder.
4. Diameter of the handle was found 450 mm to improve the grip and comfort while operating the handle.
5. Capacity of the machine was increased by 5.2% and 10.5% for green and dry fodder respectively for male workers similarly for female workers the increase was 6.02% and 9.71% for green and dry fodder respectively
6. Average heart rate for female workers were recorded as 114.27-109.65 beats/min for chaffing of green fodder with existing and modified machine respectively and 111.97-112.00 beats/min for chaffing of dry fodder. In male workers average heart rate was found to be 112.20-108.83beats beats/min during chaffing of green fodder and 114.69-110.50 beats/min during chaffing of dry fodder with existing and modified machine respectively.
7. Observations of average oxygen consumption rate of female workers was found to be 0.62-0.57 l/min for green fodder and 0.64-0.59 l/min for dry fodder with existing and modified chaff cutter. Similarly for male workers, average oxygen consumption rate were determined as 0.6 -0.56 l/min for

chaffing of green fodder and 0.63- 0.58 l/min for chaffing of dry fodder with existing and modified machine respectively.

CONCLUSION

Based on the result of various experiments conducted under the study the following conclusions were drawn. The chaffing operation included dry and green fodder (i.e. paddy straw and Napier grass). The different ergonomical and mechanical parameters were measured which included heart rate and, body temperature, blood pressure, oxygen consumption rate, energy expenditure rate, length of chaff, machine efficiency and cost of operation

1. The developed interventions are very effective in preventing the chaff cuter injuries to a great extent. The developed interventions could be fitted to most of the chaff cutters and are very cost effective.
2. The simple design of safety gadgets makes it possible for rural artisans to fabricate and retrofit on existing chaff cutters in rural areas.
3. Physiological parameters like heart rate, oxygen consumption rate and blood pressure increases more rapidly in female farm workers than male workers.
4. Heart rate and oxygen consumption rate increases during dry fodder chaffing compared to green fodder chaffing.
5. Decreased length of chaff was found after modification of chaff cuter.

SUGGESTIONS FOR FUTURE WORK

Based on the performance tests it was felt to be appropriate that the manually operated chaff cutter may be refined on the following lines for more improved base performance. The following suggestions are given for future research and development of the manually operated chaff cutter.

1. In future power operated chaff cutter with different mechanism can be fabricated and tested.
2. The implement may be tested for different types of fodder.
3. Long run test may be taken up for performance evaluation.

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APPENDICES

APPENDIX- A

Instruments used for measurement

a. Spring Dynamometer

Type	:	Warehouse hanging
Frame	:	Aluminum
Weight	:	1.5
Capacity to weight	:	0-100 kg
Least count	:	0.500 kg
Made in India	:	India

b. Thermometer

It was used for measuring the body temperature of the animals.

Type	:	Digital clinical thermometer
Reading display	:	Both in Fahrenheit and Celsius
Company	:	HICKS thermometer C-26.Industrial Estate, Aligarh, 202001

c. Stethoscope

A precision medical instrument made by Micro-tone Deluxe, was used for the measuring of the heartbeat of workers.

d. Digital Blood pressure measurement

It was used for measuring the plus.

Type : Digital contact type

Accuracy : 0.05% ± 1 digit

e. Venire Caliper

It was used for measuring length,wirtth, and thickness of materials

Least count : 0.001

f. Weighing Balance

For measurement of weight of male and female workers

Range : 1 to 500 kg

g. Measuring tape

It was used for measuring length,wirtth, and thickness of materials

Measuring capacity : 3 m

APPENDIX - B

Table B-1 Specifications of modified chaff cutter

S. No.	Description	Observations
1	Height of chaff cutter, mm	Adjustable
2	Width of chaff cutter, mm	920
3	Length of chaff cutter, mm	1200
4	Number of blades	2
5	Diameter of flywheel, mm	5800
6	Size of throat, mm	55 x 227
7	Recommended clearance b/w fixed and rotating blades, mm	9
8	Type of feeding	Manually
9	Length of feeding tray, mm	675
10	Top of chute covered, mm	450
11	Stand height of chaff cutter, mm	7500
12	Diameter of handle, mm	40
13	Length of warning roller	225
14	Diameter of warning roller	50

APPENDIX - C

Cost of operation

Economics of Digging

Cost of operation of developed prototype animal drawn turmeric digger.

Assumption

Purchase price (Rs)	=	10,000
Expected life (N)	=	8 years
Annual use h/year (L)	=	240 h/year
Salvage value, % (S)	=	10 % of cost price
Annual interest on investment, %	=	12 %
Repair & maintenances	=	% of initial cost
Housing/Insurance cost	=	1.25 % of initial cost
Wages of operator (skilled), ` / h	=	25
Hire charge of bullocks pair, ` / h	=	37

a) **Fixed costs**

1. Depreciation
2. Interest
3. Housing
4. Insurance

1. **Depreciation, Rs/h**

$$\text{Depreciation} = \frac{P - S}{N} \times \frac{1}{h}$$

Where,

P = Purchase price of the implement, 1500 Rs.

S = Salvage value, @ 10 % of purchase price

= 0.1 × 10,000 = 1000 Rs.

N = Total life in year taken as 5 years

h = Annual working hour, 240 h/ year

Depreciation = (10,000-100)/ (1 × 240)

= 4.68 ` / h

2. Interest, ` / h

Interest = $\frac{P+S}{2}\times\frac{1}{h}\times\frac{r}{100}$

= (10,000 + 1000 × 12)/(2 × 240 × 100)

= 2.75 ` / h

Where,

r = Interest @ 12 % per annum

3. Cost of housing/Insurance, ` / h

$= P\times\frac{h}{100}\times\frac{1}{120}$

$=\frac{10{,}000}{100}\times\frac{1.25}{240}$

= 0.52 ` / h

Where,

h =Housing/Insurance @ 1.25 %

Fixed cost of planter `/h = (a + b + c)

= 4.68 + 2.75 +0.52

= 7.95 `/h

b) Operating cost per hour

1. Repair and maintenance
2. Wages
3. Hire charge

1. Repair and maintenance

Repair and maintenance cost was taken of initial investment

$$= p \times \frac{m}{100 \text{ x } H}$$

Where,

m = Repair and maintenance @ 5 %

P = Purchase price

H = Annual use, 120 h

$$= \frac{10{,}000}{100} \times \frac{5}{240}$$

= 2.08 `/h

2. Wage of labour per day = 200 `/day

   Number of working hours per day = 8

   Cost incurred by labour per hour = 25 ` / h

3. Material cost = 40 Rs per qu.

Total operating cost = 2.08+25+40

= 67.03 ` / h

Total cost per hour = operating cost + fixed cost

= 67.03 + 7.95

= 75.03 ` / h

66

VITA

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