

**DEVELOPMENT OF GREEN TENDER COCONUT
SPLITTER-CUM-PUNCHING MACHINE FOR TRIBAL
POPULATION OF BASTAR REGION OF
CHHATTISGARH**

M.Tech. (Agril. Engg.) Thesis

By

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**DEPARTMENT OF FARM MACHINERY AND POWER
ENGINEERING**

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**DEVELOPMENT OF GREEN TENDER COCONUT
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POPULATION OF BASTAR REGION OF
CHHATTISGARH**

Thesis

Submitted to the

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by

Mood Mothilal Nayak

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
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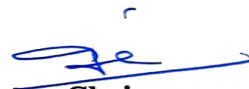
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CERTIFICATE-I

This is to certify that the thesis entitled "**Development of green tender coconut splitter-cum-punching machine for tribal population of Bastar region of Chhattisgarh**" submitted in partial fulfillment of the requirements for the degree of the **Master of Technology in Agricultural Engineering** of Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of bonafide research work carried out by **Mood Mothilal Nayak** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigation have been duly acknowledged.


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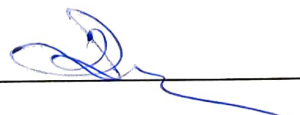


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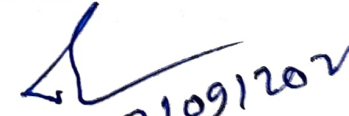
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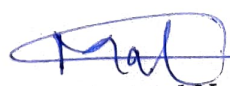
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(Mood Mothilal Nayak)

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LIST OF NOTATIONS

Notations	Description
%	Per cent
&	And
°C	Degree centigrade
cm	centimetre
m	Metre
avg.	Average
dia.	Diameter
h	Hour
ha	Hectare
ha/h	Hectare per hour
h/ha	Hour per hectare
i.e.	That is
kg	Kilogram
kg/h	Kilogram per hour
kg/s	Kilogram per second
mm	Millimeter
min.	Minute
m ²	Square meter
W	Weight Horse
hp	Horse power
cm ²	Square centimeter
N	Newton
Kgf	Kilogram force
θ	Theta
×	Multiplication
°	Degree
₹	Rupees

LIST OF ABBREVIATIONS

Abbreviations	Full name
F AE	Faculty of agricultural Engineering
Agri.	Agriculture
Agril. Engg.	Agricultural Engineering
ASAE	American Society of Agricultural Engineers
C.G.	Chhattisgarh
et.al.	Et alibi
etc.	Et cetera
Fig.	Figure
ICAR	Indian Council of Agricultural Research
IGKV	Indira Gandhi Krishi Vishwavidyalaya
B. Tech.	Bachelor of Technology
MS	Mild Steel
M. Tech	Master of Technology
S.No.	Serial Numbers
FMP	Farm Machinery and Power
Max.	Maximum
Min.	Minimum
Dept.	Department
IS	Indian Standard

THESIS ABSTRACT

- a) Title of the Thesis: Development of green tender coconut splitter-cum-punching machine for tribal population of Bastar region of Chhattisgarh
- b) Full Name of the Student: Mood Mothilal Nayak
- c) Major Subject: Farm Machinery and Power Engineering.
- d) Name and Address of the Major Advisor : Dr. A. K Dave
Professor & Head(FMPE), SVCAET&RS
- e) Degree to be awarded: Master of Technology in Agricultural Engineering


Signature of Major Advisor


Signature of the Student

Date: 29.06.2021


Signature of Head of the
Department

ABSTRACT

India coconut cultivation is more concentrated along the coastal areas which contribute about 90% coconut cultivated area with 90% production. However, states like Chhattisgarh have emerged as non-traditional areas for the cultivation of coconut with a total of 1561 ha area and annual production are 12.6 million nuts. It learnt that cutting of coconut tender is cumbersome process which involves trimming of head for sipping of coconut water followed by splitting to get coconut meat. During cutting process, cultivator/ vendor has to apply force and carry the coconuts' weight in hand which needs muscular effort. Similar, procedure is being preferred across the Bastar for coconut cutting with chopping knife having long blade (radius of curvature) and short handle. So, the challenges faced by the farmers of Bastar would remain same as additional area. It is therefore, ergonomical evaluation of adapted traditional method in Bastar has been investigated. It is found that local sickle and knife is not suitable for tribals and it create callous in hand palm. Thus, a low-cost coconut splitting cum punching machine for green

tender coconut is fabricated. The developed machine is able to punch the hole in tender coconut for sipping the water whereas it cuts the coconut into two halves to get coconut meat. The punching force observed to be about 178N whereas cutting of green tender demands 645N. The machine is fabricated using simple lever and spring mechanism. The developed machine found faster enough compared to existing traditional method and easily portable. Further, it was economical for tender coconut vendors. The use of machine reduced the drudgery of workers and hand injurious which intern save money of medical treatments as well as reduce the absentia of workers from the workplace.

शोध सारांश

अ) शोध शीर्षक	- "छत्तीसगढ़ के बस्तर क्षेत्र की आदिवासी आबादी के लिए हरे कोमल नारियल को फाड़नेवाला-सह-छिद्रण यंत्र का विकास"
ब) छात्र का नाम	- मूड मोतिलाल नायक
स) मुख्य विषय	- कृषि यंत्र एवं शक्ति अभियांत्रिकी विभाग
द) प्रमुख सलाहकार का नाम और पता	- डॉ अनूप कुमार दवे प्राध्यापक एवं विभागाध्यक्ष कृषि यंत्र एवं शक्ति अभियांत्रिकी विभाग कृषि अभियांत्रिकीय संकाय
इ) सम्मानित उपाधि	- कृषि अभियांत्रिकीय में मास्टर ऑफ टेक्नोलॉजी


प्रमुख सलाहकार के हस्ताक्षर

दिनांक 29/06/2024


छात्र का हस्ताक्षर


विभागाध्यक्ष के हस्ताक्षर

सारांश

भारत में नारियल की खेती में तटीय क्षेत्र लगभग 88 प्रतिशत क्षेत्र का योगदान देते हैं एवं उत्पादन में 90 प्रतिशत की हिस्सेदारी है। हालांकि छत्तीसगढ़ राज्य नारियल की खेती हेतु गैर-पारंपरिक क्षेत्र है, यहां लगभग 1561 हेक्टेयर क्षेत्र नारियल की खेती हेतु उपयोग में लिया जाता है जहां से वार्षिक उत्पादन लगभग 12.6 मिलियन नट है। यह ज्ञात हुआ है कि हरे नारियल को काटना बोझिल प्रक्रिया है जिसमें नारियल के गुदे को खाने के लिए विभाजन के बाद नारियल के पानी को पीने के लिए ऊपरी भाग की छंटाई शामिल है। नारियल को काटने

के प्रक्रिया के दौरान कृषक/विक्रेता को बल लगाना होता है और नारियल का वजन हाथ में लेना होता है। इस कार्य हेतु मांसपेशियों के प्रयास की आवश्यकता होती है। इसी प्रकार की प्रक्रिया जिसमें लंबे ब्लेड वाले चाकू जिसका हैंडल छोटा हो नारियल काटने के लिए बस्तर में पसंद किया जा रहा है। इसलिए बस्तर के किसानों के सामने चुनौतियां भी पारंपरिक क्षेत्र जैसी ही रहेंगी। इसलिए बस्तर में अनुकूलित पारंपरिक विधि के इर्गोनामिकल मूल्यांकन की जांच की गई एवं यह पाया कि स्थानीय हंसिया और चाकू बस्तर के श्रमिकों के लिए उपयुक्त नहीं है और यह हाथ की हथेली में घाव पैदा करती है। इसलिए हरे नारियल के लिए एक कम लागत वाले नारियल विभाजन सह पंचिंग मशीन का निर्माण किया गया है। विकसित मशीन नारियल पानी को पीने के लिए हरे नारियल में छेद करने में सक्षम है एवं नारियल का गुदा प्राप्त करने के लिए नारियल को दो भागों में काटती है। अध्ययन से ज्ञात हुआ कि हरे नारियल में छेद करने में एवं काटने में क्रमशः 178N एवं 645N बल की आवश्यक होती है। यंत्र को सरल उत्तोलक तथा कमानी तंत्र का उपयोग कर निर्मित किया गया है। विकसित मशीन मौजूदा पारंपरिक विधि की तुलना में शीघ्र कार्य पूर्ण करता है एवं सरलता से एक स्थान से दूसरे स्थान पर ले जाया जा सकता है, साथ ही साथ यह किफायती भी पाया गया। यंत्र के उपयोग से श्रमिकों को हाथ की चोट से बचाव होता है एवं कम परिश्रम से हरे नारियल को फाड़ने एवं छिद्र करने में सहायता मिलती है। ऐसा करने से श्रमिकों के चिकित्सा खर्च में कमी एवं कार्य में उपस्थिति बढ़ती है।

CHAPTER- I

INTRODUCTION

Coconut is cultivated over 95 countries across the world. The countries like India, Indonesia, Philippines and Sri Lanka together accounts for nearly 80% of total world coconut production. In India coconut cultivation is more concentrated along the coastal regions like Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Orissa, Goa, West Bengal, Pondicherry, Maharashtra, Islands of Lakshadweep and Andaman and Nicobar etc. Out of these states and union territories Kerala, Karnataka, Tamil Nadu and Andhra Pradesh contribute about 88% coconut cultivated area and 90% production. Due to this states are known as traditional area for coconut cultivation in India. However, many other states like Assam, Gujarat, Madhya Pradesh Bihar, Tripura and Chhattisgarh have emerged as non-traditional areas for cultivation of coconut. Many districts of Chhattisgarh state like Bastar (Jagdalpur), Kanker, Dantewada, Kondagaon, Dhamtari, Sukma and Bijapur have shown interest in coconut cultivation and in terms of area it is about 1561 ha. The annual production from such districts are 12.6 million nuts in the state of Chhattisgarh. The major coconut growing districts are Kondagoan, Jagdalpur, Dhamtari and Kanker accounts about 82 % of the total area and 93% of coconut production in state. Therefore, it seems that the growth of coconut cultivation area is at par when compared with traditional area of coconut production.

It is evident that Chhattisgarh state is being gradually increasing in its area of coconut cultivation and production. So, there are many challenges faced by the farmers would be similar to farmers of traditional area. It has been observed that traditional area are facing lot of difficulties in making appropriate tool and machinery for the coconut grower though mechanization level of India is gradually increasing day by day with the introduction of innovative tools and machinery (Victor et. al. 2002). But all the innovations are limited to grain crop, vegetable and selected fruits. There are various hand tools and machinery available for the coconut production like post hole digger for planting the coconut plant, power weeder for weeding and earthling operation and few models of coconut tree climber for harvesting the nuts.

Coconut is considered as holy fruit for various rituals in Hindu religion and used as a token for greeting the guest of honour. Hence, the coconut fruit is not only used for sip of water and coconut meat. The dried coconut is also used in most of the worship. Coconut vendors are used to sell about 100s of green coconut(tender) per day for the purpose of coconut water and to offer the coconut tender to the customer its head has to cut properly. The cutting of head would make convenient passage to sip water to do the same vendor has carry coconut tender in hand and cut it. During this process vendor has to rotate coconut tender and apply force simultaneously which is tedious task and not gender friendly. It requires lot of muscular effort and holding force. In other case, vendor use to cut coconut head by keeping it at platform and apply force for cutting. Later process is more convenient comparatively. Such methods are traditionally adoptable by the coconut vendors. They prefer chopping knife comprises blade having long radius of curvature and short handle to apply grater force.

Coconut water is a natural, healthy, nutritious drink forms naturally in the fruit and contains 94% water and very little fat. Coconut water has a sweet, nutty taste. It contains easily digested carbohydrates in the form of sugar and electrolytes (Zulaikhah, 2019). The tender coconut water has a therapeutic effect containing various nutrients such as minerals, vitamins, antioxidants, amino acids, enzymes and growth hormone (Prema and rajmohan, 2012). The recent studies have shown that tender coconut water is rich in L-arginine, a free form amino acid, and vitamin C, which can prevent heart disease and lipid (Lukose, 2013). Tender coconut water also contains various important compounds for the body, such as magnesium, potassium, calcium, selenium, methionine, zinc, iodine, manganese, boron, molybdenum and phyto-hormone such as auxin, cytokines, gibberellins (Prathapan and Rajamohan,2011:Fife,2008). A study conducted by Priya and Ramaswamy (2014) showed that tender coconut water has a beneficial effect, significantly lowering MDA levels and increasing levels of antioxidant enzymes. Tender coconut water improve mitochondria and provide protection against isoproterenol (free radical) induced damage (Kumar et al., 2013).tender coconut water could lower total cholesterol (TC), low-density lipoprotein (LDL) and triglycerides (TG) levels and decrease height-density (HDL) (Tkachenko and Kurhalyuk, 2011).

It is well known that India is one of the biggest producers of coconut. There is lot of advantages of consumption of tender coconut water, but so far only fifteen per cent of produced

tender coconuts are being used for tender coconut water consumption ([https:// economic times. indiatimes.com/news/economy agricultural /tender—coconut-consumption-booming-in-the country / article show / 4229635cms](https://economic.times.indiatimes.com/news/economy/agricultural/tender-coconut-consumption-booming-in-the-country/article-show/4229635cms)). For every 100 soft drink outlets there are only three of four tender coconut outlets (John, 2011). The consumer has to depend on a vendor to cut and punch the tender coconut can be one of the limiting factors for consuming coconut water. Due to the technique essential to cut and punch the tender coconut, the business is Centre don street vendors who possess skill in opening a tender coconut. Low consumption of tender coconut water may be related to difficulty in the processing of tender coconut while consuming.

In Bastar (CG), it is learnt from the survey that the process of chopping the tender coconut is very tedious and prone to hand injuries. One has to expertise and experienced in cutting and operation of tool otherwise severity of injuries would be more. Hence, utmost care and skill are required to chop the coconut in traditional way. In view of this one may merely pertained that the cutting tool and machine could be brought directly from the traditional coconut grown areas like Kerala, Andhra Pradesh, and Karnataka and provided to farmers of Chhattisgarh for their disposal. However, one has to consider the design parameters and constraints of tools and machines. Traditional devices are currently in use, such as the blade and spear which are dangerous and minimal productive tool. Based on this realization, development of a machine is need indeed that could minimize the injuries and simplifies the conventional cutting process with enhanced productivity for use population and coconut industry as well.

The selected hand tool and machine could be suitable for the local population since it has gone under several research modification based on local anthropometric and parameters (Tiwari et. al. 2020). Moreover it is matter of concern that physical body dimension of selected population may not be similar for the two states. Therefore, it is obvious that the design of tools and machine would differ at inter-state in view of handle height handle diameter, radius of curvature and overall weight of machine along with material of construction (Tiwari, 2019). In view of mention fact, the investigation has focused to fabricate a low-cost coconut splitting cum punching machine for tender coconut. This machine could be able to punch the hole in green tender coconut for sipping the water while it cut the coconut into two halves to get coconut meat. The use of this machine would reduce the drudgery of coconut vendors and farmers involved and reduce the annual amount of hand injuries like cut in figure, callus and related muscular

disorders which in turn can save money of medical treatments as well as reduce the absentia of workers from the work place.

Tender coconut vending is one the common street vending business. It is at its peak in summer season specially. The method of punching coconut is tough a strenuous. The common traditional tool used for making a hole for tender coconut is a hand sickle. This method is unsafe, messy and has high risk of injuries. This conventional method cannot be done by everyone as it requires practice and skill. Dressing (cutting the head portion) of green tender coconut requires comparatively more time before it punches for serve. One should have expertise in cutting the coconut. Roshini *et al.* (2009) stated that the major problem the tender coconut vendors faced in developing countries like India was punching and splitting of tender coconut. In view of considering the above facts, following objective have been set for the investigation with the intention that completion of work would provide a cost effective and gender friendly efficient green tender coconut punching cum splitting machine for the betterment of coconut vendors and farmers of Bastar region of Chhattisgarh.

OBJECTIVES

1. To survey the status of coconut production and prevailing practices and tools for coconut cutting in Bastar region of Chhattisgarh.
2. To study the standard design parameters of some existing coconut cutting machine and judge the suitability with farmers of Bastar.
3. To develop and fabricate coconut splitter cum punching machine ergonomically suitable for tribal population of Bastar region.

CHAPTER- II

REVIEW OF LITERATURE

To full fill the research objective of the research program, literature around the globe has been reviewed. The literatures are related to coconut cutting, coconut punching, ergonomically consideration in machine design and their application and principals have been investigated thoroughly. Out of several reviewed articles few of them are being presented here in view of coconut cutting and injuries involved in it. These are as follows:

2.1 Coconut Cutting Mechanism

Fulmali and Bhagya (2015) studied cutting of coconut for commercial purpose. The purpose of this research is to develop test and evaluate the young coconut fruit cutting machine. To reduce the cost of fabrication the two operations can be done simultaneously there is no extra attachment is required for performing the operation.

The force required to make a punching a tender coconut and for slicing a tender coconut it measures to 251N and 807N by Mownesh and Mehta (2015). They developed an automatic punching and slicing tender coconut. The punch cum splitter tender coconut is operated by pneumatic system. The time required for both punching operation is 10 second and 15 second. Two methods of tender coconut open one is the conventional method one is manual operated punch cum splitting.

Nagarajan and Sundarajan (2015) proposed a design for removal of husk from the coconut. In this there are two pneumatic actuators are used. One is placed at the bottom of structures for holding the coconut where as another is placed on the top of the structured connected with hinge joint for peeling the husk. The actuations are controlled by the DC solenoid valve. After the de-husking process the coconut shell is taken to the next stage. Oneof the pneumatic actuators is being used.

Rajankanth and Reddy (2015) this project is mainly design to cut and punch the coconut by using the compressor. This necessitates developed a punch cum splitting the tender coconut.

The focus in the development of a manually operated coconut punches cum splitting for extracting coconut water and coconut meat. The concept was selected using Pugh matrix and concept scoring, matrix. The selected concept mainly consists of punch operated by a lever and torsion spring mechanism for splinting the tender coconut is placed in the rest position and the lever is raised and operated to split the tender coconut to extract the meat the selected concept is further analyzed in terms of its functionality and cost.

Sangolkar *et al.* (2015) developed multi point cutting tool machine it is versatile machine it can be used in agriculture nursery and food processing industries. This machine has tool changing arrangements for coconut punching and cutting. This machine is economical as well as accident free and easy to carry. The design is simple and economically efficient for any person for operating machine there is no electricity required because it is operated by hand.

For de husking and breaking the coconut, a machine was developed by James *et al.* (2016) the major theme of the machine was that there is no contact between the tool and hands of the user both in breaking and grafting of the coconut. Such machine has been tested for about 45 coconuts. The complete exercise to finish within 5 minutes and all the coconut were found to be broken in first attempt.

Sharma *et al.* (2016) developed a machine for street hawkers to reduce his effort for punching and cutting of coconut water. Earlier there are uses of conventional cutting method in which they use sharpened knife. Due to such knife, they may get injure during cutting. This machine has provision to hold and lock coconut where pulling the piercing tube from the tender coconut.

Pandiaraj (2010) designed a small tender coconut opener for household usage. It was a small handy tool made up of stainless steel. It was a steel tube molded with plastic handle. The end of the stainless tube had a cutting profile in reversed saw tooth shape with sharp cutting edges along the periphery. It had smooth cutting edges in the clockwise direction. It also had a plastic molded stem in the middle for pushing out the materials inside the tube. In the top end of the stem a snap fit was provided for locking sharp cutting edges to avoid accidents. One more snap was provided in the stem for cleaning purpose.

In order to open the tender coconut the snap provided at the top was pressed and the plastic was pulled outside providing space for making the hole. The tender coconut has to be held in position with one hand and with other hand the coconut opener was first rotated in clockwise direction so that the smooth cutting edges cut soft tender coconut fibers. Then it is rotated in anti-clockwise direction where the sharp saw tooth helps in cutting the hard shell of tender coconut. Then the stainless tube was removed out of tender coconut and also to lock it in position. For cleaning purpose the plastic removed completely outside of the steel tube by pressing the snap present in the middle.



Fig 2.1: Tender coconut opener

Punch cum splitter was designed to make a hole in the tender coconut easily by Pandiaraj in 2010. This tool had a container at the base with two components, one for storing tender coconuts and the other for storing consumed tender coconuts along with leveling screws. On the top of the container the punching and splitting machine was placed. The punching machine contained a stainless steel tube with a profile at the end to pierce the tender coconut. To reduce the friction between inside of the tube and pierced tender coconut cork the entry diameter was reduced to some distance. The piercing tube was moved up and down using a manually operated lever. The punching machine has a locking device to hold the tender coconut while pulling the piercing tube from the tender coconut. The locking device has one fixed base in the middle and two sliders. The stainless steel tube was fixed in the inner slider which was guided through two fixed plastic guides.

The fixed base has a lengthy slot in both sides with many square teeth, for locking purpose. The outer slider was freely sliding in the fixed base and has locking mechanism in both sides, which will be controlled by the inner slider will releases the locking mechanism which will lock the outer slider with the fixed base. After piercing the tender coconut, till the inner slider touches the outer slider, the outer slider will lock the tender coconut and after that will be lifted along with the inner slider. Pending upon the size of the tender coconut, the outer slider will be locked to the square teeth in the fixed base.

Two level height adjustable tubular bases were provided at center of the punching tube to plate the tender coconut. The splitting was done using a stainless steel blade fitted with extended lever. The base of the splitting blade was placed at certain angle, to transfer the cutting load to the Centre of the frame. A stopper has been provided perpendicular to the base frame to place the tender coconut in a balanced position. Two semi-circular rods were fixed on both the sides of the base frame to improve the tender coconut seating and for cutting the scoop. one tray were provided at bottom of the top unit, to avoid spillage water from the tender coconut.



Fig 2.2: Coconut punch cum splitter

Anil *et al.*(2016) developed a green coconut cutting machine. This machine was mainly designed to help hawkers of tender coconut to reduce the mental fatigue and decrease the operating time for extracting coconut water. This device had both punching and shearing operations. The main parts of this machine were punch, shear, hydraulic jack, bed, gas spring and frame. The punch was of 28cm long and made up of mild steel. The shear was used to cut the coconut in to two halves. The shear had a thickness of 5cm. a rod pipe was welded on the top for providing stationary position. Hydraulic jack was main working part. It was for lifting coconut with the

help of piston for punching and shearing bed was the place where the coconut was placed. Gas spring is for movement of piston in downward position. The frame was made up of iron. For punching and shearing of the coconut initially the flow control valve of hydraulic cylinder had to be tightened by turning it in clockwise direction. Then the tender coconut can be placed on the base plate above the hydraulic piston. Lever pump of hydraulic piston can be used to raise the piston. The piston in turn rise the pedestal along with the coconut and push was against the steel rod or piston i.e., suspended from above metal frame in order to punch a hole in the coconut, for shearing operation the blade had to be moved from resting position to the level of punching rod and the lever pump of hydraulic piston was operated by pushing the lever which splits the coconut in to two halves. To restrict the piston the flow control was of light weight and can be easily assembled. Both shearing and punching can be done simultaneously. But the hydraulic were mostly proved to leaks and continuous wear and tear requires more force.

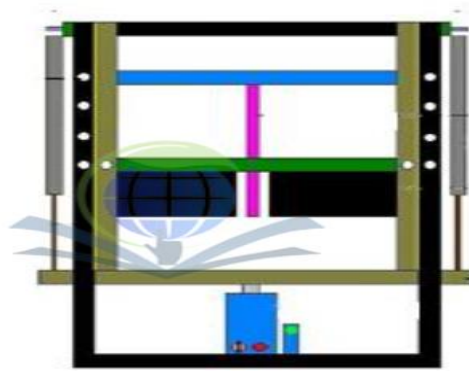


Fig 2.3: Green coconut cutting machine

Pistulkar and zakiuddin (2017) designed a coconut punch cum splitter for tender coconuts. They observed that the conventional method used for tender coconut punching and splitting had difficulties and cannot be performed by women, aged and handicapped people. In order to overcome this problem, they created a coconut punch cum splitter tool, big pulley, small pulley, belt, chain, pedal, handle, seat, big sprocket, base frame and coconut base. The base frame includes a seat and handle, a big sprocket along with pedals on both sides was attached to the base frame. A chain was providing as a link between big sprocket and flywheel where all energy obtained was stored. Due to the clutch mechanism the energy was transferred for small

pulley. Then it in turn rotates the big pulley attached to it by means of belt. This big pulley and pushes the both splitting and punching tool.



Fig 2.4: Coconut punch cum splitter

For punching the tender coconut, it was placed horizontally on the base plate consisting of a hole. Then by seating on the seat and holding the handle, the machine was pedalled. Due to the movement in the big sprocket the flywheel attached to it by chain also rotates. the rotated flywheel was engaged in clutch mechanism. This stored kinetic energy in flywheel was transferred to both pulleys that push the splitting and punching tool downwards forming a hole in the tender coconut. After consuming the coconut after the coconut was again placed a splitter base blade. Same process was carried out of splitting of tender coconut in to two. This machine can perform both splitting and punching at the same time. by means of this machine the energy required to punch and split a tender coconut are 712 N and 1277 N simultaneously. it takes 8 seconds to punch the coconut , and 12 second to split.

Shankara *et al.*(2016) developed a mechanical facilitator for punching and splitting of tender coconut. The mechanical facilitator was developed to reduce human effort. Basic mechanism behind the tender coconut mechanical facilitator was bases on sliding movement and hinge mechanism. This mechanical facilitator consisted of storage unit, coconut holder, column, spring arm, sliding slot, expansion spring, cordless drilling machine with holding assembly, tender coconut holder cum height adjust and splitting chopper. The unit had dimensions of 530*380*570mm with table height of 780 mm. the coconut holder has diameter of 124 mm. the column was 870 mm long and 40mm thick. The sliding slot was 275 mm long and 10mm thick.

The cordless drilling machine had capacity of 500 rpm and the model was GSR 7.2-2. The expansion spring coefficient of the spring arm was 1265.35 N/m, the splitting chopper was made of steel having length of 500mm, width of 8mm and height of 50mm. the screw rod for adjusting the tender coconut height was 25*125 mm, diameter of 12mm and taper angle is 90. The tender coconut had to be placed inside the tender coconut holder. Then by using the coconut cap opener the cap has to be opened. The tender coconut has to be placed inside hold-cum-height adjuster. The height can be adjusted by rotating the lever and screw rod. The drilling machine is brought in downward direction for piercing the tender coconut. The hole made was of 10mm diameter. After consuming the water, the tender coconut is split by means by chopper by applying the force. This machine had reduced about 85 per cent of effort than in the conventional method. But the machine was bulkier and need certain skill to punch tender coconut



Fig 2.5: Mechanical facilitator for punching and splitting of tender coconut

Quintero *et al.*(2016) have invented coconut opener for dehisced coconuts. This coconut opener was designed in order to void spillage of water during opening and easy way of opening dehisced tender coconut. it mainly consisted of two parts that were base portion and blade portion. Base portion was mainly a shallow cap with handles being extended from opposite sides of cap. This has a small aperture in the centre. The blade portion includes a disc which was having a support structure that holds the blade in the centre. The blade was sharp; hollow with

truncated cylindrical blade with cutting edge. The diameter of this blade was slightly less than that of the aperture present in the base portion. Thus, helps in free movement of the blade portion. The machine can embody on the de-husked coconut in two ways. In the first way the base portion was invented and placed on the top of the tender coconut. Then the blade portion is thatched from the base part aperture. After the tender coconut was flipped upside down the blade part is tapped on a firm surface with force thus penetrating the truncated cylindrical blade into the coconut. The coconut was flipped back and the blade portion is removed by rotating the disc of the blade part which removes the husk. Due to its truncated ship the opening aperture helps in easy removal of husk from cylindrical blade. The base may not be removed. For the second embodiment the entire tool was placed upside down on a firm surface and the coconut was forced on it making it firm to the coconut. Then the coconut along with the opener was flipped and the blade portion with disk is removed by rotating forming a hole in the coconut.

Mownesh and Ashok (2015) had designed a machine that can punch cum split tender coconut. It was a power operated machine. It was mainly designed to improve the access for coconut cutting and punching with less effort. This mainly consisted of seven parts: i) air compressor, ii) pneumatic cylinder, iii) direction control valve iv) hose pipe, v) punching bit vi) cutting blade and vii) supporting frame. The pneumatic cylinder has double acting cylinder motion pattern. The full bore piston diameter is 63mm and piston rod diameter is 20mm. The working pressure range of the pneumatic cylinder is 1 to 10 bars. The operating temperature range is -50 to 70 degree cent grades. The operating speed of the machine was 50 to 800 mm/s. The punching bit is made up of stainless steel for corrosive resistance. It has length of 70 mm and other 20 mm is provided to remove dust particles. The slicing blade is 30 cm long and made of stainless steel. The hose pipe is of DS2 model 5/2 type. It has type design. The maximum working pressure of this hose pipe is 10 bar and flow of 1200 lts/min.

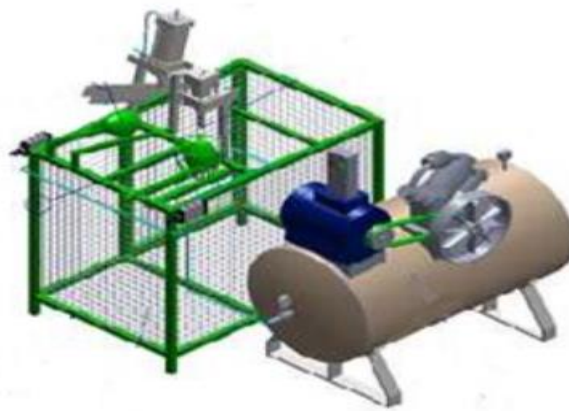


Fig 2.6: Punch cum splitter for tender coconut

The punch cum splitter for tender coconut is operated by pneumatic system. The tender coconut had to be placed on the holder ring and kept in place. The actuated air compressor supplies compressed air to the pneumatic cylinder. The solenoid valve had to be pulled down then the pneumatic cylinder which had the punching bit will be making a hole in the tender coconut by moving the punching bit downward. It comes back to its position by pushing the bottom of valve. After consuming the water it was placed on another side of frame for cutting. The cutting blade was attached to another pneumatic cylinder. Button of the solenoid valve has to be pulled then the cutting blade slices the tender coconut into two halves with the similar mechanism use for punching. By pushing the solenoid valve the cutting blade returns to its original position. This machine was bulkier and the machine was costly.

Vaibhav *al.* (2015) developed coconut water extracting machine. It was mainly designed to lessen the human effort and require no steel to operate. The parts of the machine were punching tool, lever, guide and frame. The punching tool was 10cm long with a Sharpe end. The splitting tool had thickness of 5cm with a small rod welded at one end for controlling the movement. Lever had a diameter of 2cm and 90cm long. The distance between the point of punching and point at which efforts has to applied was 70cm. A metal guide was provided to restrict the motion of punching tool. Frame was the basic structure on which others components were placed. It was made up of iron. The other parts are made up of mild steel to avoid corrosion.

Satip and Kiattisak (2008) developed semi-automatic cutting machine for young coconuts. The machine was namely designed for coconut juice industries. The design concept of

this machine was the fruits by applying pneumatic press. The machine mainly consisted of 5 parts. They were 1) machine frame 2) cutting base 3) knife set 4) pneumatic system and 5) tanks for receiving coconut juice and coconut fruits. The machine parts that come in contact with the edible parts of fruits are made of food-grade stainless steel. The pneumatic cylinders are used for lateral movement of cutting base. These pneumatic cylinders are 28cm long 1.6cm diameter. They were placed on both sides of cutting base. The maximum force 2535N at 25cm/min loading speed was selected for this design of machines. The pneumatic system has the pressure of 7bars. a sharp knife was mounted on a steel frame.

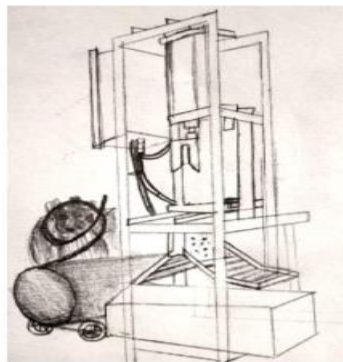


Fig 2.7: Semi-automatic cutting machine for young coconuts

Fulmali and boyars (2015) have developed a multipurpose coconut cutting machine. It was designed mainly to improve the efficiency of the coconut vendor in cutting tender coconut with less effort and manpower. The machine mainly consisted of three parts, such as 1) the screw jack with a coconut holder arrangement 2) the removable cutting blade and 3) the pointed tool with a nut arrangement. The threads of jack contain British Standard Whitworth (BSW) 38mm which is the standard screw jack available in the market. The cutting tool was made of stainless steel. The length of blade was 17cm with a thickness of 5mm. the blade was provide with threaded bolts of BSW 12mm which helped in holding the blade in fixed position. The hole making drill had threads with BSW 10mm and with nut arrangement to hold the tender coconut in fixed position. The entire coconut cutting machine height was 38cm and width was 30cm.



Fig 2.8: multipurpose coconut cutting machine

Balachander *et al.*(2018) developed the tender coconut cutting machine. The machine was mainly designed to reduce the effort. Level of skill required and risk of injuries while cutting the tender coconut. The tender coconut cutting machine consisted of bar rods to hold the equipment and form a frame. Lever was providing for applying the pressure for punching and cutting the coconut. Knife was given to split the coconut into two halves. Spring was provided to regain the position of the levers. The main concept of the machine was punching by means of lever and torsion spring mechanism. The basic principal was to apply pressure to cut and punch the coconuts. Initially the tender coconut has to be placed in the circular box and the lever has to be attached to closed coil. The pressure has to apply on the lever to punch a hole in the tender coconut. After removing the pressure, the lever will come to its original position due to the tension of spring. After removing the water coconut has to place in rectangular tray and pressure has to be applied on the lever to split open the coconut in to two halves by means of knife. By this machine coconut cutting has become a simple operation and does not require any skill. Though the machine was highly efficient as there was no grip to hold the coconut in position it resulted in high risk of injuries.

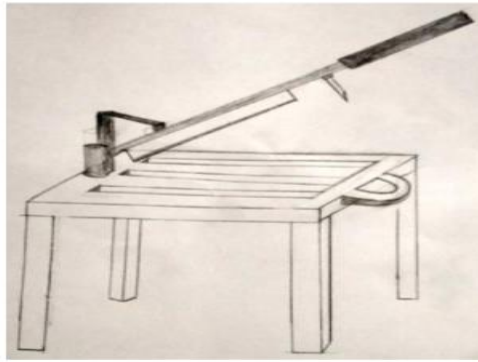


Fig 2.9: Tender coconut cutting machine

In 2018, George *et al.* fabricated a prototype of tender coconut trimming piercing and draining system. The machine frame consists of three sections, trimming, draining and punching. It was observed that that direction of placing the coconut knife parallel to the coconut did not successfully cut the coconut into half. Further, the direction of placing the coconut fiber was perpendicular to knife-edge in which the fruit cut effectively.

Thomas (2012) designed a tool for opening a tender coconut. Their main aim was to design tender coconut punching tool in order to provide access to coconut water for everyone. The coconut opener has mainly two parts the upper cutting part and lower base part. The upper part mainly consisted of serrated cutting element with a handle. The handle was cylindrical for maintaining rigidity. The upper part was hollow stainless steel tube of 6cm diameter. The upper part of the handle contains three regularly spaced protrusions with rounded edges. They were provided for grip and support for cutting. These protrusions may vary with different shapes like square, disc... etc. The lower base part resembles an inverted funnel shape; the upper part contains a circular opening that is therefore for receiving the cylindrical portion of upper part. The circular base part was of diameter 12.5 cm with an array of fins extended from the underside to provide support for the coconut. These were the parts that come in contact with tender coconut. The coconut was held in vertical position with one hand and the crown was covered with the base part. The fins present inward of the base part provide grip on coconut. Then the upper part was introduced in circular opening of the base and rotated in order to make holes into the coconut. The coconut husk was removed by pressing down the handle down, unlike other coconut opener it makes holes of about 6cm which also provide to coconut meat.



Fig 2.10: Tool for opening a coconut

Barrett (2011) had designed a fruit coring system that can be used as coconut opener and also to cut fruits. This coconut opener was also termed as fruit coring system. It consisted of mainly two assembly, such as i) a coring assembly which had a hollow tube with a sharp serrated edge on one side with inner threading with two rods attached perpendicularly on other side to provide support. ii) A coring assembly had another tube with a spring shaped corkscrew in the end. Its diameter was less than the coring assembly. It had a gripping ring as a handle to operate it.

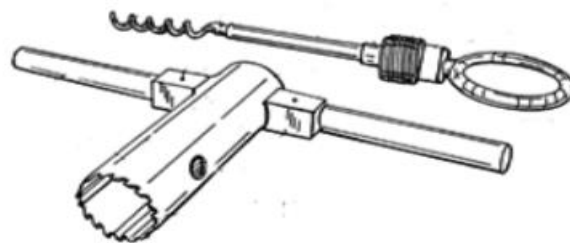


Fig 2.11: Coconut opener

To punch hole in the tender coconut first the coconut has to be placed horizontally then on centre of the coconut side the cork screw has to be pushed into the tender coconut. That helps in knowing end of the tender coconut. Then the coconut has to be held with hand. With other hand the coring assembly has to be rotated along the teeth side into the coconut until it reaches the end. Then in counter rotation with that of coring assembly the corkscrew was rotated to remove the coconut cork properly.

2.2 Accidental and Anthropometry Scenario

A study conducted by Mittal *et al.* (1996) in Punjab state pointed out that out of 36 injury causing agricultural incidents reported from twelve villages during a one year period, 3 (8.3%) were fatal, and 33 (91.7%) were non-fatal. The incidence rate/1000 machines/year was highest for tractors (23.7), followed by sprayers (15.5), electric motors (7.1), threshers (5.7), and chaff cutters (2.2).

In the world a large proportion of the work force is involved in agriculture or related occupations. In many countries, farming is a part of the unorganized sector. Also it is not well covered by insurance or health services. Farmers work under constraints weather conditions, making injury inevitable. Very often, they work alone and an injury-producing event may not be noticed for a long time. Farm injuries are considered by Kumar (2000) to be severe, as quite a significant percentage (20%) result in permanent disability. If farmer gets disabled by agricultural injuries he may not be further trained for any other work. This causes greater economic loss to the family. In India, tractors are reported to be involved in 5% of injuries and through spades and sickles 46% of farm injuries occur.

In all, incidents due to agricultural hand tools with an incidence rate of 0.08/1000 hand tools/year. Hand tool injuries defined as the disability less than two days. The highest incidence rate was reported for sickles (0.16), followed by pickaxes (0.09). Injuries due to sickles mostly occurred while harvesting hard-stem crops like pigeon pea, chickpea, mustard, sorghum, and fenugreek. The total number of victims who sustained fatal or non-fatal injuries was 82, of which 79.3% were farmers and 20.7% were agricultural laborers. Males constituted 92.7% of the victims, while 7.3% of the victims were female. The highest number of victims was in the age group of 30–44 years (45.1%), followed by 15–29 years (32.9%), above 45 years (17.1%), and below 14 years (4.9%).

Nag (2004) the number of total hand tool-related accidents was found to be higher than the national average of 8%. The other agricultural accident accounted for 60% of the total accidents. The incident rate of other agricultural accidents in Arunachal Pradesh (3.84 per 1000 workers/year) was found to be higher as compared to 1.12, 0.7, 0.23 and 0.38 per 1000 workers/year in eastern, northern, central and southern regions, respectively

Kumar *et al* (2008) studied that sickle injuries were most often sustained by left hand fingers. The injury caused due to gathering and holding crop by left hand while harvesting crops also blade touched the finger of left hand causing deep cut injuries. The right hand is used for cutting by holding the tool. It was also observed that right hand was injured by already cut crop stubbles and rubbing against ground/field surface while harvesting crop close to ground. It was estimated that there were 1683 hand tool related injuries per hundred thousand per year.

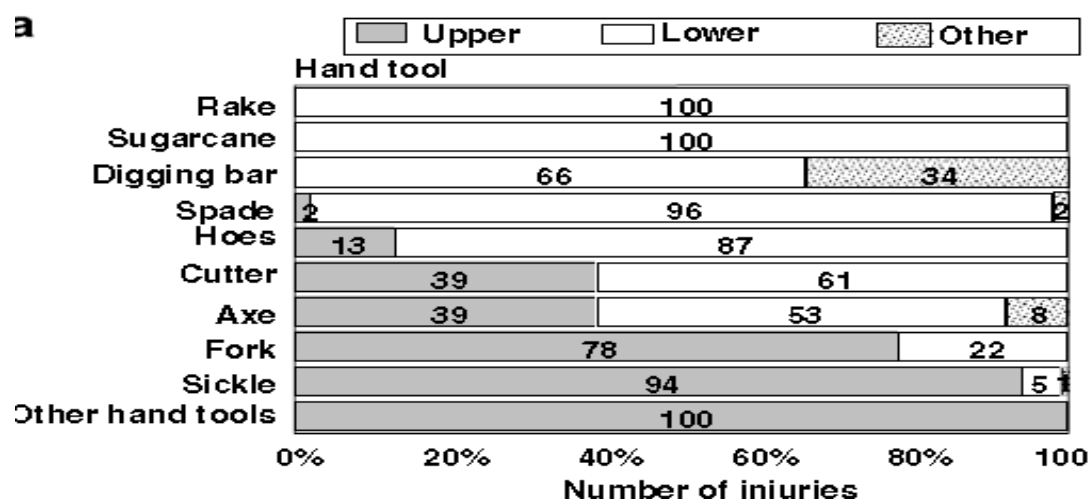


Fig 2.12 Body regions injured in hand tool injuries

Kumar (2009) analyzed that most of the accidents resulted in cut (33.14%) injury by hand tools, like dao, spade and sickles. During slashing of shrubs, fencing, bund or channel making and harvesting cut type injury occurred. Due to lack of personal protective equipment to fingers, foot, knee, fore hand, etc. causes cut type injury. Furthermore, slashing of shrubs using dao is one of the heavy operations in shifting cultivation Dewangan *et al.*, (2004), which results in early fatigue to workers. Thus, operation in fatigue state and desire to quickly finish the task results in injury. Carelessness during operation of spade and sickle and illness prior to the operation was also the cause of accidents. It was also observed that most of the victims (one-third) were in the age group of 40–49 years (fig 2.2).

Patel *et al* (2010) conducted the survey in Etawah district of Uttar Pradesh and reported 106 agricultural injuries. The number of injuries were found highest in serrated sickle (16) followed by plane sickle and khurpi (weeding fork) ten each (20), spade (5) and kudali (pickaxe)

and chopper knife one each (2). Injuries in serrated sickle (Fig. 2.3) occurred while harvesting wheat and paddy.

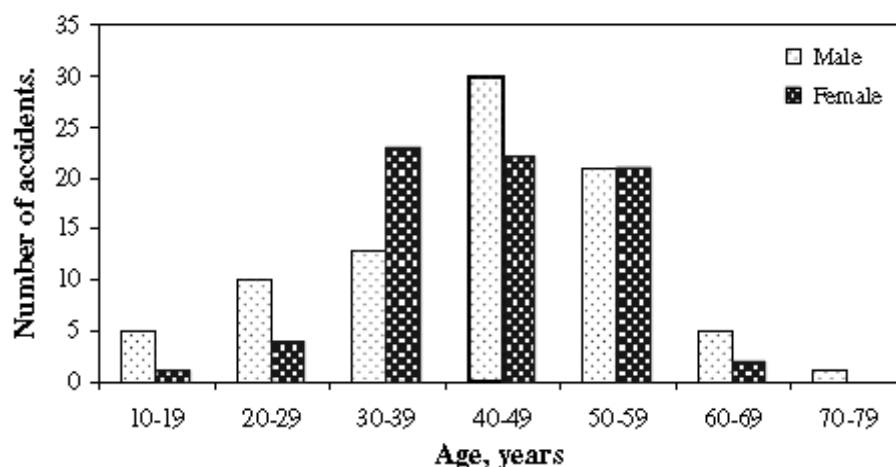


Fig. 6. Age and sex of agricultural accident victims.

Fig 2.13 Age and sex of agricultural accident victims.

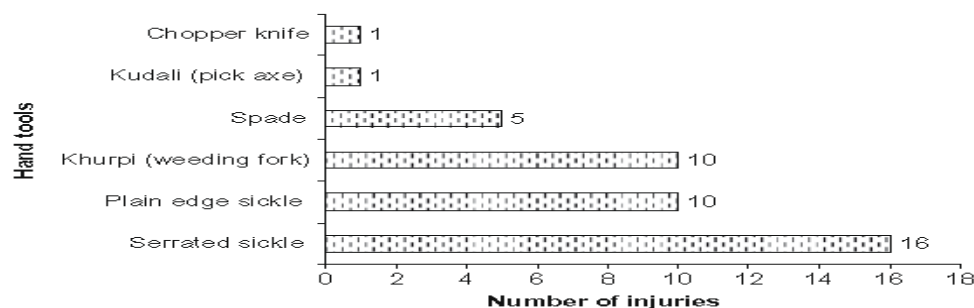


Fig. 5. Hand tools associated with injuries.

Fig 2.14: Hand tools associated with injuries

2.3 Anthropometric Data of Agricultural Workers

The detailed anthropometric survey in of India is important because the body dimension of Indian population varies from region to region Majumdar (1972).

Rahi (2003) conducted anthropometric survey of 100 agricultural workers of Rajasthan State. He identified 28 body dimensions for farm machinery design. The mean stature is 1667 mm and 1537 mm for male and female agricultural worker and body weight were 53 kg and,

44.3 kg respectively. The straight line relation was obtained between the body measurements and stature for agricultural workers of the region.

Gite and Majumder (2007) reported 79 body dimensions useful in farm equipment design of around 6000 agricultural workers from 12 States of India. The mean stature and weight of agricultural workers ranged between 1633 ± 68 mm and 54.7 ± 8.7 kg for male workers and 1515 ± 61 mm and 46.3 ± 7.8 kg for female workers respectively. The average values of strength data for pushing and pulling were measured. The average pull force was observed 224 N for male and 143 N for female. Similarly about 218 N and 158 N for female were observed as pulling force for male and female respectively

As far as the strength of leg is concerned for pedal thresher Agrawal (2008) reported that downward leg force is greater when foot is at 16% of the stature. The 5th and 95th percentile value of stature of the NE region is 1526 mm and 1730 mm respectively. Hence for maximum leg force, the foot height should be 244 - 277 mm and this is the recommended height of foot pedal. Therefore to accommodate the operator height of the pedal should be changed from 244 - 277 mm.

Agrawal *et al.* (2010) gave the repository of anthropometric data of central India. The workers were within the age group of 18-60 years with average age of 30 years for male and 33 years for female. The vertical measurements are highly correlated with stature where coefficient of correlation (r) varying from 0.75-0.9 for both male and female workers. Furthermore, sitting height is linearly correlated ($r=0.75-0.85$) with vertical grip reach sitting, sitting eye height and sitting acromion height.

They collected anthropometric data from 20 districts of various agro-climatic zones of Madhya Pradesh on 1700 agricultural workers. The mean age, stature and mass of the male subjects were 29.5 years, 1649 mm and 55 kg whereas for female subjects the values were 33.7 years, 1519 mm and 45 kg, respectively. The isometric push/pull strength of female subjects was lower than those of male subjects. The mean values for isometric push and pull strength in standing posture with both hands were 242.4 N and 231.0 N, respectively for male workers and (175.5 ± 33.9) N and (159.4 ± 42.9) N, respectively for female workers. The mass of the subjects indicated a positive correlation with isometric push/pull strength.

For the handle design of sickle Dewangan *et al.* (2010) studied that while gripping the handle the finger which is longest should not touch the palm. Also it should not be more than the internal grip diameter. Hence the recommended handle diameter is 3.7 cm.

Koley and Melton (2010) investigated about 800 subjects aged between 6 - 25 years from Amritsar, Punjab, India to collect three anthropometric measurements, namely height, weight and Body Mass Index (BMI) and analyze the trend of handgrip strength. The result of the study indicated a gradual rise of both the handgrip strength from 6 to 23 years in males and from 6 to 21 years in females. The mean values of all the three anthropometric variables for males were found higher than females.

Ratn *et al.* (2010) stated that age, gender and BMI accounted for 60%-75% of variability in muscle strength. Differences in most hand dimensions between five age groups were found by Chandra *et al.* (2011).

Sengupta and Sahoo (2012) carried out study on 15 young male tea-garden workers under the age group of 18-25 years of West Bengal. They found that there is a significant difference in body surface area, BMI, percentage of body fat, blood pressure, physical fitness index, energy expenditure, anaerobic power, mean upper arm circumference, thigh circumference, waist circumference and buttock. But no such significant difference was observed in calf circumference and waist-to-hip ratio.

More and Vyahare (2014) presented sixty four anthropometric and grip strength parameters in which weight and age are included of agriculture workers of Marathwada region of Maharashtra. Dimensions such as bodyweight, stature, bicep breadth, popliteal height (sitting), and buttock popliteal length were found to be 56.9kg, 165.1cm, 39.9cm, 44.3cm, 58.1cm etc. respectively.

Chhattisgarh being the nontraditional area for coconut cultivation, no study has been done so far on coconut related machineries used for coconut splitting cum punching work. However, some anthropometric observations related work for tribal women has been carried out in reference to crop harvesting and weeding operation. It has been reported in many reviews that such work of coconut splitting cum punching required proper expertise and knowhow. Therefore looking to strength of Bastar region of farmers a work has been planned to work on Development

of Green Tender Coconut Splitter-cum-Punching Machine for Tribal population of Bastar region of Chhattisgarh.

CHAPTER-III

MATERIALS AND METHODS

In this chapter the details of methodology adopted to complete the work as per objectives are presented. The first part of the study was related to survey work to record the status, followed by development and testing of developed equipment. The survey provides important information for research depending on its purpose (Tiwari and Shrivastava, 2016). The survey depends on the representativeness of the population concern. To perform, a survey proforma is essential which consists of a number of questions and respondents have to answer in a set format. Further distinction could be made between open-ended and closed-ended questions. An open-ended question asks the respondent to formulate his own answer, while closed-ended question ask the respondent to pick an answer from a given of options. The response options for a closed-ended question must be exhaustive and mutually exclusive. A respondent's answer to an open-ended question could be coded into a response scale and afterward analyzed. Such methodology has helped in understanding the status of coconut production and prevailing practices in Bastar region of Chhattisgarh.

3.1 Survey for the Study

This chapter presents the methodology of present investigation chapter take care of complete materials used in the experiments with their detail. The chapter has been discussed under major heads like survey, existing machinery available for coconut cutting followed by their evaluation methodology. After detailed discussion of mentioned head step by step process of development of coconut punching cum splitting machine has been presented.

3.1.1 Development of questionnaire

The knowledge available with regard to coconut cutting in the market was not known. To gauge the impact of coconut in market, a questionnaire was designed as presented in Annexure I. The questionnaire was prepared to know the status of coconut production, prevailing practices and traditional tools etc used in Bastar region of Chhattisgarh. A survey has been conducted in twenty percent of selected districts of Bastar region. The selection of districts has been done on the basis of their coconut production. In such districts the vendors are purchasing coconut from

nearby villagers and selling in different locations of districts. Due care was taken for selecting the subjects and districts. The districts was selected namely Bastar, Kondagoan, Narayanpur, Kanker and Sukma of Bastar plateau region. A door to door survey has been performed in which farmers having coconut field were interviewed personally one by one and filled the information in the questionnaire. Analyses and reporting of filled proforma was carried out at later stage. There was no honorarium paid to the respondent. It is informed to farmer that the proposed work is being carried out for good cause and for their betterment which would increase working efficiency as well as reduce drudgery. The different type of traditional tools used for cutting the coconut was investigated and its design specification has been presented in chapter IV. Further, the problems associated during cutting of coconut and related injuries have been discussed and recorded.

3.1.2 Components of questionnaire

The survey proforma or questionnaire has been prepared in two parts namely part-I and part-II. Part-I deals about information about coconut grower like quantity of coconut, family involvement, land holding experience in coconut growing, market of coconut at local level, pricing and expansion of coconut area in selected districts or localities. Similarly, part-II is exclusively designed to assess the requirement of machine for the vendors, grower and tribal of Bastar region.

PART-I

Survey Questionnaire for Coconut Grower

Interviewer's names

Date of interview

Occupation

Address

Photo

Would you be willing to participate in an interview for about 30 minutes? If yes, then proceed

1. Do you grow coconut

☐

Yes

☐

No

2. Do you sell coconut to

☐

Vendor

☐

Self?

3. Has your family involved in coconuts selling or coconut products in 2019?

4. What is the use of coconut? 1. Water ☐ 2. meat ☐ Yes ☐ No ☐ 3. worship ☐ 4. all ☐
5. What is stag of maturity when harvest Green ☐ Dry ☐
6. How much land do you have available for farming? Acres
7. How much of your land is used to grow coconuts? Acres
8. How many coconut trees are there on your field?
9. What are the variety Kera Bastar?
10. When was the last time you planted coconut trees? Year
11. Do you harvest coconuts from other people's land? YES ☐ NO ☐
12. How much do you pay for coconuts harvested from other people's land?
13. How many coconuts do you harvest from other people's land?
- Coconut per week
14. Did you buy mature coconuts? YES ☐ NO ☐
15. At what price? Per nut
16. Is there anything you would like to mention, ask or remark about this survey?
17. What would be the expected production as per yea? nut/year
18. How many nuts could be there per plant in year? nut/year.
19. What is age of trees?
20. How do you see the buyers?
21. Comments over coconut production in this area.

We thank you very much for your participation.

Signature Enumerators

PART-II

Questionnaire to access requirement of machine

1. Do you sell coconuts? ☐ Yes ☐ No
2. How to harvest coconut from tree? Machine / climber
3. How many coconuts per day?
4. What do consumers preferred 1.Meat 2.Water 3.Dry 4.Other
5. How do you cut the coconut 1. Knife 2.Machine
6. How do you hold coconut 1. Hand 2. Use wooden log 3.
7. Average weight of coconut < 1 kg and > 2kg
8. Action of cutting of coconut impact/shearing/compress
9. Tools specification.....
10. Any injury.....
11. Business is profitable...
12. Do you heard of any machinery?
13. Is there any need of machine?

3.2 Study Area

The study conducted in non-traditional area of coconut planting of Bastar region comprises seven districts of Chhattisgarh state. This includes the districts namely Bastar, Kondagoan, Kanker, Dantewada, Bijapur, Sukma and Narayanapur of Chhattisgarh. Out of such districts Bastar is little urbanized and the district headquarter of Bastar is Jagdalpur situated between $19^{\circ} 4'N$ latitude and $82^{\circ} 1'E$ longitude at 552 m elevation. Bastar is among the largest districts of Chhattisgarh and acquires an area of 10469.50 km² the geographical area about 135,191 km². The district is bordered by Nowrangpur and Koraput towards east and Malkangiri district of Odisha towards South-East. To the west is the upper part of Uttar Bastar, Kanker and Narayanpur. The south and lower South West is Dantewada. Uttar Bastar, Kanker is in North and Dhamtari is in North-East (Anonymous, 2019). The total population of Bastar is about 1.42 million people in which tribal dominated about 70%.

The Bastar has sub humid moist climate with annual rainfall of 1453 mm annually. The geographical area of Bastar comprises forest land about 51%, cultivable land about 40%, pasture

land about 5% and fallow land 4%. The biodiversity and agro climatic of Bastar is identical to Kerala. Thus local people call it as mini Kerala. The climatic parameters like rainfall, temperature, relative humidity, wind velocity, sunshine hours and pan evaporation etc. has been taken from mini weather station established by Indian Meteorological Department under Gramin Krishi Mausam Seva GKMS project at SGCARS Jagdalpur. The average of maximum yearly temperature is about 36⁰ C with 40% RH. The average annual temperature suggested that the temperature of this region ranges from 9.42 ⁰C to 36.4 ⁰C with RH up to 83 %.The table 3.1 presents the average normal temperature of other selected districts of region. Bastar plateau zone is nontraditional area for coconut, but the climatic parameters clearly indicate that it's a suitable place for coconut cultivation.

Table 3.1 Average normal temperature and relative humidity of Bastar region.

Districts	Normal temp (° C).		RH, %
	Min.	Max.	
Bastar	9.42	36.4	83
Kondagoan	9.42	36.4	83
Kanker	13	30.0	60
Narayanapur	23	43	54
Dantewada	10	30	59
Sukma	27	39	64
Bijapur	20	32	51

3.3 Assessment of Existing Machine

To look into the design aspect and fabrication technique, three popular coconut cutting machine have been selected. Such machinery was from traditional area of coconut such as Tamilnadu, Karnataka and Kerala. The productions of coconut in such states are quite high compare to other parts of India. Further, mechanization level in coconut industries has also been increased in such states and observed to be adequate enough for the user population. It is therefore three different coconut cutting machine have been selected to analyse the design, development, material of construction and comfort level of the user. It is expected that the specification of such machinery could provide better design input for the development of similar

machine for the Bastar population since; Bastar is non-traditional area of coconut production and the mechanization level of coconut limited. Cutting of coconut involves major operation such slicing, cutting to get meat from coconut for eating purpose. However, coconut can be directly, purchased for sipping coconut water. Both the cases are limited to green tender. Thus all the three machinery those involved in cutting of green tender, have been selected namely machine1 (Fig 3.2), machine2 (Fig 3.3) and machine3 (Fig 3.4). Machine-1 designed to punch and split the green tender coconut while machine-2 was designed for coconut cutting specifically. Similarly machine-3 marketed as multipurpose coconut cutting machine since it does cutting and punching simultaneously.

3.3.1 Design of selected machinery

The assessment and comparison of existing machinery has been done on following point.

1. Purpose of use
2. Engineering design
3. Cutting mechanism
4. Material of construction
5. Applied forces
6. Ease of operation
7. Economics involved
8. User population

Further the performance of selected machinery has been judged using body part discomfort rating scale and questionnaire (Tewari and Shrivastava, 2013). To investigate the design parameters of coconut cutting machine, three different machines has been identified and selected for the study purpose (Fig 3.2 to 3.4). The selected machinery has been considered based upon popularly among vendors of Andhra, Telangana, Tamilnadu and Kerala etc. Such machinery is similar in operation. However, the specifications of each machine differ significantly to compare the design (Agrawal, 2008). The design specification along with selected parameters has been identified and discussed below.

The cutting blade in both the models was sharpened at one edge and it was 700 mm long, 80 mm wide with 8 mm thickness. Two 50x5mm size MS flat strips were provided on the cutting platform to support and hold the tender coconut in position.

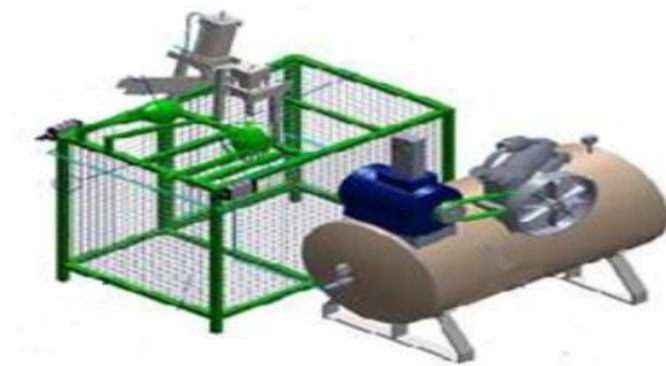


Fig 3.1: A view of semi automatic punch cum splitter for tender coconut



Fig 3.2: A hand operated model of tender coconut cutting machine



Fig 3.3: Multipurpose standing and sitting model of coconut cutting machine

Applied forces

The full bore piston diameter is 63mm and piston rod diameter is 20mm. The working pressure range of the pneumatic cylinder was about 1 to 10 bars. The basic principle of the project is to apply the pressure to cut and punch the coconuts. Initially coconut is placed in the circular box. After that lever is attached to closed coil .The pressure is applied on the lever to punch the coconut.

The coconut cutting machine has following dimensions. Its height is about 38 cm and the width is 30 cm with a platform and the threads of jack is BSW 38(it is the standard screw jack available in market, the threads of cutting tool blade holding nut is BSW 12 mm and the hole making tool is of 10mm

1. Material of machine: The mild steel is mostly used in agricultural sector. It is easily available, better strength and less cost compared to stainless steel. It requires very little repair and maintenance.

2. Weight of machine: The objective is to develop coconut splitting machine for easy portability. So that one can easily transport from one place to another and installed for operating purpose. It has been observed that human can lift the weight of about 40% of its weight so it was decided that dead weight should not exceed the 25-30 kg considering 70 kg of body mass of tribal population of Bastar.

3. Height of machine: The mechanism is decided to work in standing posture by applying muscle force by hand. It is therefore decided that the height of machine may be maximum height may not go beyond the waist height of the selected population.

4. Width of machine: The width of machine allows comfortable cutting of tender coconut and keep them aside for next cutting. It is therefore decided that the platform should have width to keep one coconut each side from the centre and must not extent beyond then should width of selected population this allow comfortable for given population.

5. Length of machine: The machine bed holds the knife along its length. Thus the length of machine bed may not go beyond the forward reach of the selected population. The knife is well supported by the extreme mechanical bed while another end would be in grip of user for

applying force. Thus it is similar to cantilever mechanism in which knife end is fixed at far end another near to user there is also one arrangement at far location hold the knife in non-working condition.

6. Handle length: The handle length has been decided based on the length of coconut and also there is consideration of applying less force to cut coconut by having longer length. So the length of handle match with the length of 40% of blade and rest of handle lever.

7. Grip diameter: The grip diameter decided on the basis of applying higher force.

8. Length of cutting unit: The length of the cutting unit must place in the middle of the handle were the coconut is placed so that it is easy for cutting the tender coconut.

9. Holding jaw for cutting: It has been observed that the different shape and elliptical shape for feasibility of working.

10. Fixing arrangement: All the components of the machine are placed with proper arrangement so that it can be easy for punching and splitting of tender coconut

11. Overall dimensions of machine: The overall dimensions are taken as per the requirement.

12. Punching tool diameter: the punching tool diameter helps in easy penetration in to the tender coconut while punching in to the tender coconut for sipping of water.

13. Length of punching tool: The punching tool must be of stainless steel so that it can be protected from rusting while punching in to the tender coconut. The length of punching tool is around 20cm, so that it can easily penetrate in to tender coconut for punching.

14. Holding ring for punching: The holding ring should be place correctly downwards to the punching tool for keeping the tender coconut in the ring for punching the tender coconut. It is made up of iron.

15. Reaction frame: The frame is a structure of machine on which the other components are placed. It is made up of iron.

16. Water receiving tray: The tray placed at downwards for receiving the tender coconut water after splitting or after punching. If tray not provided means the water will go as a waste.

3.4 Engineering Parameters of Coconut

Size is necessary to describe any object defined with some dimensional parameters (Fig 3.5). The geometric dimensions of coconut namely length, width and thickness were determined. Hundred coconut were selected randomly and the geometric dimensions were measured by using digital vernier caliper (Mitutoyo DIGIMATIC CALIPER 500-144CN-10) (Mitutoyo Corporation, Japan) having least count 0.01 mm.

3.4.1. Average length (L), width (W) and thickness

Average Length (L), Width (W) and Thickness (T) were calculated as followed (Singhal and Samuel, 2003).

$$L = \frac{\sum_{i=1}^n L}{n}$$

$$W = \frac{\sum_{i=1}^n w}{n}$$

$$T = \frac{\sum_{i=1}^n T}{n}$$

Where,

L=Length, mm

W= Width, mm and

T= Thickness, mm

3.4.2. Geometric mean diameter (D_p).

The geometric mean diameter (D_p) was calculated by using the following relationship (Mohsenin, 1986).

$$D_p = (LWT)^{1/3}$$

Where,

L=Length, mm,

W= Width, mm,

T= Thickness.

3.4.3. Sphericity (φ)

Sphericity defines the ratio of the diameter of a sphere of the same volume as that of particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle (Sahay and Singh, 1994). This parameter shows the shape character of coconut relative to the sphere having the same volume.

$$\text{Sphericity} = \sqrt{\frac{\text{Volume of the onion bulb}}{\text{Volume of circumscribed sphere}}} = \frac{(\text{LWT})^{1/3}}{\text{L}}$$

Where,

L = Length, mm,

W = Width, mm and

T = Thickness, mm.



Fig 3.4: Measuring of coordinates of coconut dimensions.

3.5 BPDCR/ Discomfort rating score

For the localization of different body part discomfort score the body diagram as shown in Fig. 3.6 divided in to 27 numbers of regions, on the basis of Corlett and Bishop Technique, the body diagram chart used during the experiments. For the same the subject was asked to mention all body parts with discomfort, starting with the worst and the second worst (Fig 3.7) and so on until all parts were mentioned (Agrawal et. al., 2010). Then after that subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on (Ratn et. al., 2010). The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The subjects were asked

to locate the body parts with respect to degree of discomfort in the order as extremely heavy, very heavy, moderately heavy, heavy, light and very light. The scores given in that order were 6, 5, 4, 3, 2 and 1.

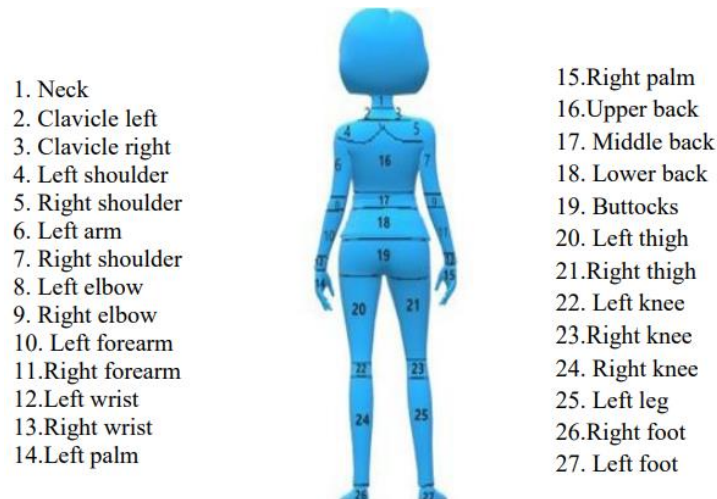


Fig 3.5: Body map showing different region for knowing BPDS (Corlett and Bishop, 1978)

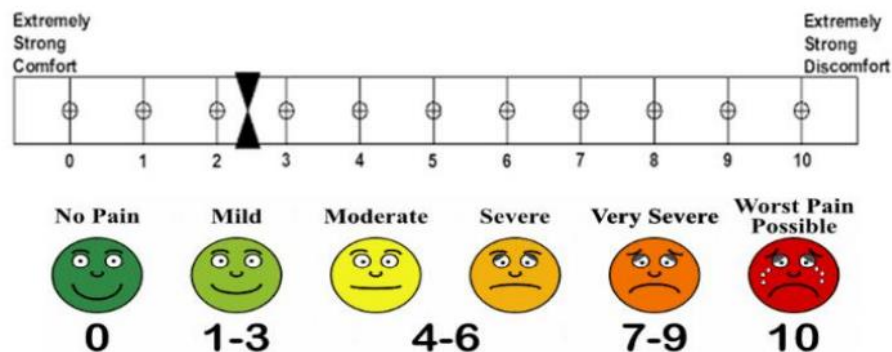


Fig 3.6 Visual analogue discomfort scale for assessment of overall body discomfort (Borg, 1982)

3.6 Design Methodology

To develop the coconut splitting cum punching machine for the Bastar region of Chhattisgarh, some anthropometric dimensions have been identified based on the design consideration of existing machine discussed under section 3.3.1. The total of 10 body dimensions has been identified along with age and weight of user population. About 100 tribal of Bastar have been considered for the measurement of anthropometric dimension out of 100 tribal 40

were women and 60 were men age group between 25 to 40 years. The details of identified anthropometric dimensions are as follows.

The anthropometric dimensions of 15 farm workers of selected villages of Bastar district were identified. The selected vendors were fit for agricultural task and do not have any physical abnormalities (Sengupta and Sahoo, 2012). All the identified anthropometric dimensions of Bastar tribal were studied and measured. All the dimensions were in standard erect condition posture. All the anthropometric dimensions were investigated for their minimum, maximum and average value etc. The coefficient of variation of the entire measured dimension was also calculated (Sharma, 2016). The definition and details of identified dimension are presented below;

1. Iliocrystale height: The vertical distance from the standing surface to the height of the illospinale. The subject stands erect and looks straight forward.
2. Elbow height: The vertical distance from the standing surface to the top of the radial. The subject stands erect and looks straight forward.
3. Waist Circumference: The circumference of the torso at the waist level. The subject stands erect and looks straight forward.
4. Biacromial breadth: The transverse distance across the shoulder from right to left acromion. The subject stands erect and looks straight forward.
5. Elbow width: Elbow breadth is measured by first raising the right arm to the horizontal position and flexing the elbow to form a right angle.
6. Acromion height: The horizontal distance from the front tip of the. Saddle to the front most point of the grip
7. Shoulder height: Vertical distance from the floor to the acromion (i.e. the bony tip of the shoulder). Applications: The approximate center of rotation of the upper limb and, hence, of use in determining zones of comfortable reach; reference datum for location of fixtures, fittings, controls etc.

8. Grip diameter: The distance between the joint of the 1st and 2nd phalanges of the thumb and knuckles of the middle finger measured with the hand held to the grip
9. Hand length: defined as the distance from a line connecting the radial stylium (the most distal point of the styloid process of the radius) and the ulnar stylium (the most distal point of the styloid process of the ulna) on the palmar side to the tip of the middle finger
10. Hand width: The distance from the tip of the thumb to the tip of the little finger on your outstretched hand.
11. Weight: The amount at which subject weighs.

Measurement of Anthropometric Parameters of Bastar Tribal Anthropometry deals with the measurement of physical body dimension of human being. These dimensions could be utilized for tool design, machine design and workplace improvement to enhance the comfort and safety of the farm worker. Anthropometric dimensions comprises 79 body dimension in total which includes 43 dimensions of standing postures and 16 dimensions of sitting posture whereas other 20 dimensions are independent to the posture and related to skin to measure fat of muscle and belly (Balachander, 2018). Apart from 79 anthropometric dimensions, sixteen strength parameters namely push, pull, grip strength and torque measurement of both the sides i.e. left and right have also been included. To measure the selected anthropometric dimension, a commercial make Anthropometric (portable) was used. All the measurements were carried out with the consultation of medical experts and physiotherapists as and when required. The expert helped in identifying the different ligaments and joints for effective and realistic measurements.

Instrumentations

The instruments required for anthropometric measurement are given below and the specifications are given in appendix.

- Anthropometric Kit
- Portable weighing scale
- Sliding Caliper

- Hand Grip Dynamometer
- Spring Balance

Before the anthropometric measurements the body dimensions were understood and instruments required for the measurements were familiarized and calibrated. It was determined that about 76 anthropometric and three strength parameters were included. So as it becomes 79 anthropometric dimensions in all (Dewangan et.al. 2010). The descriptions of 79 body dimensions along with strength parameter, age and weight of the subjects are given in appendix. The standard anthropometric dimensions suggested by (NASA, 1978) were studied. The selected subjects are the true representative of the tribal population of the region. The terminologies were referred as per Anthropometric Source Book (NASA, 1978). The table shows the number of dimensions in different static position of the subject.

3.7 Anthropometric Measurement

Prior to the measurement of selected subjects, a standard proforma (Dewangan et al., 2008) was prepared. To maintain the uniformity measurement were taken from left hand side of the subject. Subjects were asked to be barefoot and standing erect for measuring the data of standing posture. The data of sitting posture were taken with due consideration of standard ortho-muscular position i.e. the sitting was made in such a way that thigh would not be in under excessive pressure. The sitting was so adjusted that the feet completely touched the ground. All the head, hand and foot dimensions are measured with the help of sliding caliper. The 76 body dimensions are categorized under three major heads i.e. standing posture, sitting posture and standing/sitting posture.

3.8 Statistical Analysis of Measured Dimensions

The anthropometric data of coconut vendors were analyzed statistically for mean, range, maximum, minimum value, Standard error (SE), Standard Deviation (SD), coefficient of variation (CV), 5th and 95th percentile was found for each body dimension. The concept of designing for the average person is an error (Shrivastava et. al., 2010).). There no such things as an average person or dimension. No one has all their body dimension at 50% point whatever size they are. Similarly designing for muscular strength based on average is also an error. The

percentile could be a better way to design the coconut cutting machine when anthropometric dimensions are in considerations. It could be determined by arithmetically using following method.

$$X_i = m \pm sz \dots$$

Where,

X_i = 5th and 95th percentile of the variable

m = Mean value of the variable

s = Standard deviation of the variable

z = Constant for the percentile concerned equal to 1.645 ('-' sign gives the 5th percentile whereas '+' sign for 95th percentile).

The Standard Deviation (SD) of measured anthropometric dimension of farm women was calculated by the following expression which shows the degree of variability in the Bastar population.

$$SD = \sqrt{\frac{\sum(x-m)^2}{n-1}} \dots (3.5)$$

Where,

SD = Standard deviation of the variable

m = Mean value of the variable

x = Individual value of the body dimension concerned

n = Number of subjects

For comparing the variability among the different selected farm women of Bastar region, coefficient of variation could be determined. Farm women are supposed to be different in terms of their anthropometric dimensions if CV comes more. Similarly, lesser value of CV comprises limited variation among the farm women group. The Coefficient of Variation is the ratio of standard deviation (SD) to mean (m) value of selected anthropometric dimension of each farm women of Bastar region. It could be expressed mathematically as follows:

$$CV = \frac{\sigma}{m} \times 100$$

The standard error (SE) of the selected anthropometric dimension of farm women is for sample population (n) could be calculated as:

$$SE = \frac{\sigma}{\sqrt{n}}$$

To know the correlation coefficient among the stature and other relevant anthropometric body dimensions, graphs and scatter diagrams were plotted.

3.9 Design Parameters of CSPM (coconut splitting cum punching machine)

3.9.1. Design of frame

1. Height: The height of the coconut cutting machine is around 70cm.the machine is in rectangular shape. Four sides it has 70cm height.
2. Length: The length of the frame is 60cm.
3. Width: The width of the frame is around 30cm.
4. Wight: The weight of the machine is 20kg.

3.9.2 Bed design

1. Material: The material used for bed design of coconut splitting and punching machine is iron.
2. Blade thickness: The blade thickness is 8mm.

3.9.3 Design of handle

1. Grip size: the grip size is designed on the basic of anthropometric dimension of Bastar people.
2. Horizontal reach: the horizontal reach from handle to the front portion of the lever.

3.9.4 Design of holder

1. Holder for splitting
2. Holder for punching

The design parameters of coconut splitting and punching machine are shape, size, handle, punching bit, cutting blade, spring supporting frame and shear. The physical and mechanical properties of tender coconut were studied since this characteristic influence the splitting and punching operation was performed by the machine. The machine frame consists of three sections (Fulmali and Bhagya, 2015). The first one has a sharp knife which cuts of the topmost portion of tender coconut. The second one has a piercing system that makes the hole at the tip of the coconut. The third component is similar to the second one but has a sharp rod with holes on it that helps in easy draining of water from the shell. Optimal settings include the shoulder knife of 70-75 cm from base and the optimal cutting angle of 45 degree (Fig 3.8).

Punching bit

Designed based on the average tender coconut dimensions by measuring the length from top of tender coconut to the water level its measures to be average of 5cm. So by giving 2cm extra length to the punching bit a total length of 7cm (70mm) is made. In the punching bit 20mm provision is provided to remove the dust particle during punching of a tender coconut. The punching material selected is stainless steel as it has corrosive resistant properties and has good strength (Fig 3.8).

Slicing Blade

Designed based on the average Tender coconut dimensions by measuring the total length of tender coconut its measures to be average of 20cm. So by giving 10cm extra length to the cutting blade a total length of 30cm (300mm) is made. The cutting blade material selected is stainless steel as it has corrosive resistant properties and has good strength (Fig 3.8).

Characteristics features of knife

The knife used for cutting the tender coconut was of mildly tempered stainless steel. It also has an excellent corrosion resistance for sanitary reasons as well as appearance. At least 14 per cent chrome was imparted for stain resistance and ductility. Higher hardness could lead to edge chipping and poor traction on sharpening steel. The knife was electroplated with Nickel coating of 2 mm for better appearance and corrosion resistance. This coating also helps in long lasting of knife (Fig 3.8).

Optimal knife angles

Optimal knife angle is important parameter for cutting the young coconut. It is the angle made between the cutting surface and the tender coconut. The optimal knife angle was found by trial and error method. Different angles were set by trial and error method by tilting the coconut at 45°, 50° and 60°, by keeping one at constant. After the trials the angle to be optimized was 45° Piercing section. The unit has a sharp needle of 5 mm to penetrate into the trimmed tender coconut. The holder was provided to hold the coconut intact while piercing. A handle was provided at the backside, to avoid the shaking while processing it. Piercing section and components the second section consisted of a simple punch set at particular height to punch the hole. The piercing hole was made sharp so that it easily pieces the outer husk and makes hole of required diameter. The piercing needle was having the diameter of 5 mm diameter for a sharp and deep piercing (Fig 3.8).

Piercing section

The unit has a sharp needle of 5 mm to penetrate into the trimmed tender coconut. The holder was provided to hold the coconut intact while piercing. A handle was provided at the backside, to avoid the shaking while processing it (Fig 3.8).

Piercing section and components

The second section consists of a simple punch set at particular height to punch the hole. The piercing hole was made sharp so that it easily pieces the outer husk and makes hole of required diameter. The piercing needle was having the diameter of 5 mm diameter for a sharp and deep piercing (Fig 3.8).



Fig 3.7: Fabrication work in the workshop

3.10 Testing and Validation

3.10.1 Time for opening tender coconut

The coconut water is available for consumption only after coconut is cut and punched. The tender coconut vender continuously cut and punches tender coconuts. Time taken for cutting and punching a tender was few seconds, to have more accuracy in the data the activity was reported five times and average time taken for cutting and punching a tender coconut was arrived and that was treated as time taken for cutting and punching a tender coconut.

Table 3.2 Distribution of sample by time opening of tender coconut N=15

Time for opening tender	Frequency (N)	Percentage (%)
Coconut in seconds		
Up to 5.17 seconds	06	20.00
5.18 to 10.34 seconds	20	66.67
More than 10.35 seconds	04	13.33
Total	30	100
Mean	8.16	
S.D	2.59	

Time taken for cutting and punching tender coconut was found to be exclusively subjective. The expensive of vender and the age of tender coconut were some of the factors that affect the time taken for splitting and punching tender coconut.

3.10.2 Time for splitting tender coconut

Splitting the tender coconut to take out white meat for eating after the consumer drinks the water was also a part of tender coconut vending. Mostly consumers ask the vendor to cut the coconut in to two halves to take out the white meat and eat. Time taken for splitting tender coconut in to two halves was also done. To have more accuracy in the data the activity is

repeated for five times and average time for splitting coconut was calculated, and that was treated as time taken for splitting a tender coconut. The mean time taken for splitting a tender coconut was found to be 12.16 seconds with a SD of 3.10 seconds. Negligible and equal proportion of the respondent's either took relatively more time or relatively less time for splitting the coconut. Slightly less than three fourth (73.34%) of the sample took between 9.06 and 15.26 seconds to split tender coconut. Splitting the tender coconut took more time than punching (Table 3.2 and 3.3)

Table 3.3 Distribution of the sample by time opening tender coconut N=30

Time for opening tender	Frequency (N)	Percentage (%)
Coconut in seconds		
Up to 18.31 seconds	4	13.33
18.33 to 31.14 seconds	22	73.34
More than 31.15 seconds	4	13.33
Total	30	100
Mean		12.16
S.D		3.10

3.11 Ergonomics Evaluation

Ergonomic evaluation of traditional method and method of punching tender coconut using the punching tools available in the market served as a base for proposing the tender coconut punching tools. The parameters selected for conducting ergonomics evaluation was (i) energy expenditure; (ii) physiological cost of work, (iii) drudgery index, (iv) body discomfort and (v) force applied (Gite and Majumder, 2007).

3.11.1 Sample selection

The tender coconut splitting cum punching machine is selected for conduction of ergonomic evaluation.

3.11.2 Field experiment

An experiment was designed to conduct the ergonomic evaluation of punching the tender coconut by conventional method and by two selected manually operated tender coconut punching tools. For the experiment 15 tender coconut vendors were selected. The parameters selected for ergonomic evaluation were expenditure physiological cost of work drudgery index, body discomfort and force exerted while punching the tender coconut. The tender coconut vendor was asked to relax and the heart rate monitor was fixed to the wrist of the respondent. In the resting phase the respondent were asked to pay close attention for any pain occurring in their body. Five reading of heart rate of the respondent with one minute intervals were taken in resting phase. Before the commencement of the activity, the respondent hand was bound with a hand band which in turn was attached to the spring balance with the help of rope.

The tender coconut vendor was asked to perform the activity without any disturbance. The respondents were asked to setup all the tender coconuts and bottle to fill up with coconut water closely to carry out the work. The tender coconut vendor was asked to open the tender coconuts and fill up the bottles continuously without any disturbances. While performing the activity five reading of heart rate with one minute intervals were noted. For every minute spring balance readings were noted for measuring force. After five minutes the respondent was asked to stop the activity and allowed to recover.

At recovery phase another set of five heart rate readings with one minute intervals were taken. Then the respondent was asked to report the intensity of exertion of the activity he perceived and measured as per Borg's rating of perceived exertion scale. To measure the drudgery, the vendors, the vendors were asked to identify the difficulty on a scale that had five levels 1 to 5, score '1' was given for very easy operation, score '2' was given for easy operation, score '3' was given for moderate operation, score '4' was given for difficulty operation and score '5' was given for very difficult operation. Higher the score higher the difficulties observed. Based on the score the difficulty score of the respondent was finalized. Performance score was measured based on the scale developed for the purpose. The performance was measured in term

of “agree”, “partially agree”, “undecided”, “not agree” and “not at all agree” and score 5,4,3,2 and 1 were given respectively. Higher the score higher comfort in performance of the tool. Then the tender coconut vendor was given the body discomfort scale and asked to report the order of the discomfort experienced in body regions for more uncomfortable to comfortable. Later they were asked to rate the intensity of body discomfort on seven point scale from 1 to 7 (i.e., 1=extremely comfortable; 2=very comfortable; 3=comfortable; 4=fairly comfortable ; 5=uncomfortable; 6=very uncomfortable; 7=extremely uncomfortable).The same procedure was repeated with the selected two manually operated tender coconut punching machines. After obtaining all the readings energy expenditure, physiological cost of work, drudgery index, body discomfort score and force were calculated.

3.11.3 Energy expenditure

Energy expenditure is a physiological measurement used to assess the influence of physical fatigue on work performance among workers (Li *et al.*, 2009; Zenz and berg, 1996). Joseph *et al.*, (2004) discovered a linear relationship between energy expenditure and heart rate. Heart rate monitors can be used for monitoring heart rates without interfering subject’s work (Vitalis *et al.*, 1986).Hence energy expenditure was calculated by the formulae proposed by Varghese *et al.* (1994). Herat rate of the subject was measured using polar heart rate monitor.

Energy expenditure of worker (Kj/Min) =0.159*average heart rate (bpm) – 8.72

Average heart rate

= 1st reading +2nd reading +3rd reading +4th reading +5th reading/ Number of times the reading were taken

3.11.4 Physiological cost of work

The energy that a person consumes can be divided into two categories. The “basal metabolic rate” is that caloric expenditure required maintaining the body in a resting state (Jerry and James. 2016). The caloric expenditure beyond the basal metabolism is the “physiological cost” of additional work (Dickey *et al.*, 1972). The physiological workload of the respondent can be determined by recording the heart at rest, during work and after compulsion of the work

(Kalitha, 2015). The formula developed by Varghese *et.al.* (1989) on the basic of heart rate and energy expenditure was used

Physiological cost of work (PCW) = total cardiac cost of work/total time of the activity

Total cardiac cost of work=cardiac cost of work +cardiac cost of recovery

Cardiac cost of recovery (CCR) =

(Average recovery heart rate –average resting heart rate) *duration of recovery

Cardiac cost of work (CCW) =AWHR*Duration of the activity

Working heart rate (WHR) =average working heart rate – average resting heart rate

Average heart rate during rest, work and recovery period was calculated using the formula given below

Average heart rate

= $\frac{1^{\text{st}} \text{ reading} + 2^{\text{nd}} \text{ reading} + 3^{\text{rd}} \text{ reading} + 4^{\text{th}} \text{ reading} + 5^{\text{th}} \text{ reading}}{\text{Number of times the reading were taken}}$

3.11.5 Perceived exertion

Perceived exertion is the feeling of how heavy and strenuous a physical task is (Borg, 1998). The central nervous system response to perceived job stress may increase sensitization to pain stimuli leading to development of musculoskeletal disorders (Devereux et al., 2004). Hence the perceived exertion of the tender coconut vendors was studied to know the level of exertion in tender coconut punching. Borg's rating of perceived exertion scale (1998) was used for scoring the perceived exertion.

3.11.6 Drudgery index

Drudgery is generally conceived as physical and mental strain, agony, fatigue and monotony experienced by human beings. Drudgery index was calculated by using the below formulae (Borah and Kalitha, 1998).

$$\text{Drudgery index} = X + Y + Z/3 * 100$$

Where, X= coefficient pertaining to difficult score

Y= coefficient pertaining to performance score

Z = coefficient pertaining to average time spent

3.12 OBPDR

Body discomfort to a vendor may be caused due to postural discomforts and force applied while punching tender coconut. Musculoskeletal discomforts and body pain during work may result due to heavy, repetitive and forceful work, working in painful or awkward postures and positions, handling heavy loads, repetition of body motions and ergonomic work methods and use of traditional tools (Vyas, 2012). Perceive body discomforts was selected as one of the variable for conducting ergonomic evaluation of the conventional method and selected manually operated tender coconut punching tools. Corlett and Bishop's body discomfort scale (1976) was selected as tool for measuring body discomfort.

CHAPTER – IV

RESULTS AND DISCUSSIONS

This chapter presents the results of the various experiments conducted during the course of the study. The analysis of the data and their interpretations including significant findings are also presented.

4.1 Status of Coconut Production in Chhattisgarh

The status of coconut of Bastar region of Chhattisgarh state has been investigated by the survey in five randomly selected districts of coconut production areas viz. Jagdalpur, Kondagoan, Kanker, Narayanapur and Sukma of Bastar region of Chhattisgarh. It was observed that the pattern of livelihood in Bastar continues in traditional ways. The survey conducted by two well-trained officers and one local boy. Officers are assigned to take basic data from Rural Extension Officer of selected panchayat and then visited the farmers' doorstep. The local boy was asked to help them in identifying the representative person and translation of local word to incorporate into questionnaire. It is learnt that Chhattisgarh covers 1561 ha under coconut with an annual production of nearly 126.17 lakh nuts out of which 1289 ha area is covered by the Bastar zone. The areas under Bastar Plateau viz., Jagdalpur, Narayanpur, Dhamtari, and Kondagoan along with Kanker accounts for nearly 81.61 per cent of the total area and 93.32 per cent of the total production of coconut in the State. Further, Bastar region of Chhattisgarh is a non-traditional coconut growing area yet there is tremendous scope of its production and exploration in the area. According to Ministry of Agriculture and Farmers Welfare, GOI (2019) during the last 5 years there is an increase of approximately 500 ha area under coconut in the tribal belt of Bastar region. The maximum area expansion has taken place in the Narayanpur district followed by Kondagaon.

The age of vendors selected for the study ranged from 28 years to 60 years. The mean age was 44 years. Mostly men were taking up vending business as compared to women. Survey revealed that primary income of local vendors depends on number of coconut sale. Vendors are purchasing the coconut from nearby wholesaler and selling in different areas. Different types of traditional tools are being used for splitting the coconut. Sometimes, such tools caused injuries to the vendor while splitting the coconut. Survey depicted that sickle is preferred tool for splitting

and punching of coconut. They sold coconut at around INR 30-50/- per piece based on their size and expected water content. The same was procuring at wholesale rate at about INR 2400 for 100 nuts.

Nearly 67% of the respondents had four to five family members. Almost 30% of the respondents had one to three family members. Only 3.33% of the sample fell into the category of families above five members from the age of the last member it can be stated that the majority of families that formed the sample for the investigation were in the expanding stage of family life cycle. The difference in the age of the last member in the family was 11.4 years. The families that formed the sample for the investigation were middle aged families. Probably this is the period where the head of the family is physically fit to take up strenuous income earning works. Most of the families involved in the investigation had two male and two female members in their family. Fifty per cent of the respondents had only one earnings members in the family. Forty per cent of the respondents had two earnings members in the family remaining ten per cent of the respondents had three earnings members. Families with more than one earning members were fifty per cent. Coconut vending business was found to be either individual or family business. Mostly tender coconut vending business was run by individual or family in few cases the individual engaged paid workers to help them in running the business.

An attempt was made to understand since how long these vendors were involved in coconut vending business. The experience of vendors in tender coconut business ranged between 12 years and 25 years. The mean years of vendors experience was found to be 17.5 years. Ten per cent of the respondents were in this business for more than twenty years. One fifth of them had an experience of six to ten years. Seventy per cent of the respondents had experience from 10 years to 20 years. On an average the vendors were selling 202 coconuts per day. More than sixty per cent of the respondents were selling 124 to 180 coconut per day. Twenty per cent of the respondents were selling more than 280 coconuts and 16.67 respondents were selling less than 124 coconuts per day. The income earned by tender coconut vendors ranged between Rs 2,000 to Rs 20,000 in a month. The mean income earned was found to be Rs 10,800. The mean profit earned by the respondents in day through tender coconut business was Rs 430. The total respondents were distributed between two socio economic classes i.e., lower middle and upper

class. Nearly three fourth belonged to lower middle class. None of the respondents were found in upper class, upper middle class and lower class.

The mean time taken for cutting and punching a tender coconut was found to be 5-6 coconuts in a minute. One fifth of the respondents took up to 10 units. Relatively more number of vendors took 10-12 seconds to cut per tender. Only 15 per cent took more than 10 seconds for cutting and punching a tender coconut. Pain in the upper extremity, stiffness in the upper extremity, soreness in the upper extremity, heaviness in the upper extremity, pain radiating from upper extremity to back is predominately experienced by respondents in the study. Cramps and numbness in neck were rarely experienced by very few. Swelling, spasms and tingling sensation in neck were never experienced by tender coconut vendors. Pains, stiffness, tenderness in the shoulder, pain scorching from shoulder to upper limb were the musculoskeletal discomforts experienced by the respondents frequently in shoulder. Tingling sensation in shoulder was rarely experienced by very few respondents. The subjects rarely experienced tingling in fingers. Back pain and discomforts in the back were the most frequently felt discomforts in the back. Inflexibility in the back was complained by few respondents frequently. Pain radiating from back to lower limb was experienced more regularly by vendors. In the local market, no machine was available to cut and punch.

4.1.1 Prevailing practices for coconut cutting in Bastar

It was observed that prevailing practice of coconut cutting are manual dominantly. Due to non-traditional area of coconut, manual cutting is more preferred over mechanical. However mechanical cutting is not popular in Bastar region. Sickles used for splitting of coconut and punching of coconut (Fig. 4.1). Apart from sickle, vendors are also using butcher knife for ease in operation. It basically consists of a curved metallic blade attached with wooden handle. Shearing forces are required to slice the top of coconut. The main part of the sickle is metallic blade made of low carbon steel. The blade is made in ling curved shape. The handle of the sickle is made of well-seasoned wood. The forged end of the blade for fixing the handle is called tang. The plain edge blade was found to be more popular.



Fig. 4.1 Sickle and knife for coconut opening and cutting

4.1.2 Geometrical parameters of traditional tools used

The shape of the coconut cutting tool found to be in C-shape while few are familiar to use butcher knife. Questionnaire suggests that vendor liked sickle much due to its lighter weight and ease in operation. The size of such cutting tool determined to be 41.3 x 9.2 x 7.6 (L X W X H) cm. The grip diameter of the handle is little lesser than the inside grip diameter. The handle material found to be non-slip material, cushioned so that blisters on the hands of the user may not form. The overall weight of the sickle found to be around 230-380 gm. Blade of the sickle has significant role in weight of sickle. Carbon steel was preferred over mild steel and other. Of course stainless steel and alloy material are lighter and have enough strength compared to carbon steel for said purpose of sickle. Specific material may not be advocated due to local availability of material. Thus, study resulted that the workers are compatible with their traditional tools but little intervention may change the output. Further gripping, weight of sickle and material of sickle has scope of improvisation. Such inputs were kept in mind when designing the splitter cum punching machine.

4.2 Design Consideration of Existing Coconut Cutting Machine

The design aspects of three popular coconut cutting machines have been studied. Such machinery was procured from traditional areas of coconut such as Tamilnadu, Karnataka and Kerala. Out of three selected coconut cutting machines, one is power operated while the other two are manually operated. Firstly, technical specification of such machinery has been compared as follows:

Machine 1

The overall schematic diagram is presented in Figure 4.2. Base platform is the base of entire system made of wood with the size of (5×4) inches. All the components like conveyor, cutting stand mechanism, drilling mechanism, all other motors and electrical components are all mounted on it. All the performance or actions of the machine are held under this area or within the base platform. Coconut holder is a device where the green coconut is placed and holds for the entire process under taken by the machine. The base structure is a rigid component of the entire mechanism, wood as a base material is considered due to the load factor. Holding jaw is the only component is in direct contact with the green coconut (Koley and Melton, 2017). There are two holding jaws in which one is rigid and other is movable. Material considered for this element is wood strongly coated with rubber. Coated rubber helps in strong grip. Rotating rod is fixed at the mid attaching to the base structure and movable jaw. Rod is made of steel and externally threaded for certain region. The movable jaw is assembled to this in order to perform translate action. The working principle or the mechanism is plain screw vice mechanism. Basically all components are rigid except movable jaw and connecting rod. The movable jaw moves to and fro on rotating the connecting rod. Conveyor is used to transfer the coconut to different task and return back to its original position automatically. Flat belt conveyor is used. Power transmission from the motor is done by chain drives. It is considered upon the factor heavy load obtained by the objects and operations performed in the machine. Two chain drives are placed on both sides of the conveyor and driven by a DC motor which is controlled by the controller. Belt conveyor is a machine transporting material in a continuous way by friction drive. It is mainly composed by rack, conveyor belt, belt roll, tensioning device and gearing. Belt conveyor is composed by two endpoint pulleys and a closed conveyor belt. The pulley that drives conveyor belt rotating is called drive pulley or transmission drum; the other one— only used to change conveyor belt movement direction—is called bend pulley. Drive pulley is driven by the motor through reducer, and conveyor belt dragging relies on the friction drag between the drive pulley and the conveyor belt. The drive pulleys are generally installed at the discharge end in order to increase traction and be easy to drag. Material is fed on the feed-side and landed on the rotating conveyor belt, then rely on the conveyor belt friction to be delivered to discharge end.



Fig. 4.2 Coconut chopping machine
a) Coconut holder b) Drill mechanism c) Final assembled machine.

Machine 2

This machine is used to cut and punch the coconuts. The basic principle of the machine is to apply the pressure to cut and punch the coconuts (Fig 4.3). Initially coconut is placed in the circular box. After that lever is attached to closed coil .The pressure is applied on the lever to punch the coconut. After removing pressure lever comes to original position by tension of spring. After removing the water coconut is placed in that rectangular tray. Apply the pressure on the lever to cut the coconut by the use of knife. It is very simple operation. It does not have more skill to cut the coconut. It is low cost compared to other manual cutting machines. It is non-polluting and eco friendly. It took around total operation time about 20 seconds including cutting and punching. It is expected to serve for at least 5 years by assuming daily usage. Manufacturing capital calculated as Rs.25000/- (welding, knife, lever).



Fig. 4.3 Coconut cutting cum punching machine

Machine 3

M3 is mainly design to cut and punch the coconut by using the compressor. This necessitates the development of a punch-cum-splitter for punching and splitting the tender coconut (Fig 4.4). The present work focuses on the development of a manually operated coconut punch-cum-splitter for extracting coconut water and coconut meat. The selected concept mainly consists of punch operated by a lever and torsion spring mechanism. When the tender coconut has to be punched, the operator places the tender coconut on the top of the holding mechanism in natural rest position and the lever is raised and pressed against the tender coconut to punch a hole. For splitting, the tender coconut is placed in the rest position and the lever is raised & operated to split the tender coconut to extract the meat. The selected concept is further analyzed in terms of its functionality and cost.

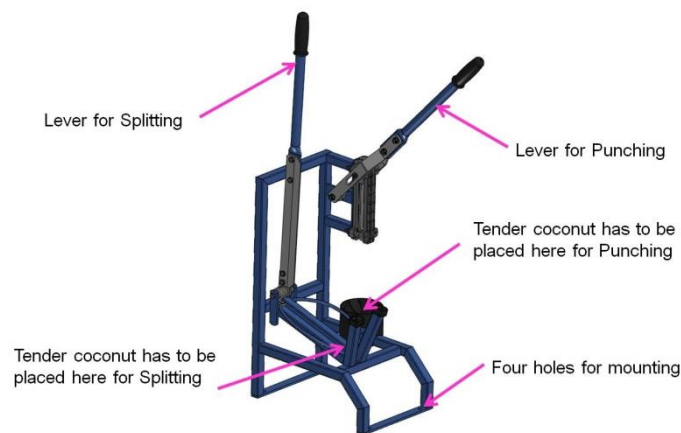


Fig. 4.4 View of coconut cutting cum punching machine 3

4.2.1 Ergonomic evaluation of selected existing machines

The purpose of ergonomics evaluation is to minimize or prevent injury to the individual and to promote workplace efficiency through the application of ergonomics. Ergonomic design helps the person to lessen muscle fatigue, inverse productivity and reduce number and severity of work related musculoskeletal disorders. Thus, ergonomic evaluation of the available tender coconut cutting machine help to understand the reasons behind less popularity of the machine and the mechanisms that is essential to increase the efficiency of tool and decrease tender coconut vendor drudgery (Kumar et. al., 2000). The tools selected for ergonomic evaluation were

the coconut punch and splitter from products household tender coconut opener with T-shaped handle. The ergonomic parameters cost of work, perceived exertion, drudgery index, body discomfort and force excreted (More and Vyavahare, 2014). All the three selected tender cutting cum punching machine tested ergonomically for the tribal of Bastar and look into the feasibility of machine. It was found that semi-automatic machine worked properly and liked by the vendors but the high cost involvement was major concern by the vendor. According to them, machine is good but cannot affordable. Ergonomic assessment of this machine found to be satisfactory in operation. Since vendor has to place tender underneath the punching box, there was not much effort involved in it (Kumar and Dewangan, 2009). Thus, the HR value found to be least in this case. While other two machines involved the operation like placing of nut and apply force due to which HR shoots and selected vendors feel uncomfortable. The ergonomical assessment of selected machines presented below;

Table 4.1 Ergonomical evaluation of selected coconut cutting and punching machine (N=12)

SN	Particulars	Machine1	Machine2	Machine3
1	Code	M1	M2	M3
2	Dead weight, kg	78	32	18
3	Coconut cutting, nuts/min	10-12	5-6	4-5
4	Heart Rate, bpm	80-95	130-140	110-120
5	Oxygen update, l/min	0.23 – 0.41	0.8-0.92	0.57-0.69
6	Energy expenditure rate, kJ/min	4.0- 6.3	11.1-13.54	8.77-10.36

The energy expenditure of coconut vendors while punching the tender coconut with coconut punch and splitters found to be heavy in manual machine. The mean energy expenditure while opening the coconut the punch and splitter was 10.03 kJ/min. Nearly seventy (68.89 %) per cent of the vendors spent energy in between 5.54 to 9.45 kJ/min while 15.56% respondents spent energy beyond 11.78 kJ/min during operating coconut punch and splitter (Table 4.1).

4.2.2 Discomfort score of existing coconut machine

Body discomfort to a vendor may be caused due to postural discomforts and force applied while punching and cutting of tender coconut. Musculoskeletal discomforts and body pain during work may result due to heavy, repetitive and forceful work, working in painful or awkward postures and positions, handling heavy loads, repetition of body motions and ergonomic work

methods and use of traditional tools (vyas, 2102). Perceived body discomfort was selected as one of the variable for conducting ergonomic evaluation punching tools. Corlett and bishops body discomfort scale (1976) was selected as tool for measuring body discomfort.

4.2.3 Feasibility trial in Chhattisgarh

The existing machines which were presented in south India were tested for the Bastar people. The energy expenditure of the tender coconut vendors while punching the coconut with tender coconut opener was divided in to high, low and medium basing in the mean and standard deviation (Table 4.2). The mean energy expenditure while operating the tender coconut opener was 7.20kJ/min. More than seventy (73.33%) per cent of the vendors spent energy of 6.3-8.11kJ/min nearly thirteen per cent (13.33%) of respondent spent energy expenditure between 5.24 to 6.3 and 13.34 per cent spent energy expenditure in between 8.11-9.15 while punching tender coconut with tender coconut opener.

Table 4.2 Distribution of the sample by energy expenditure while operating the coconut punch and splitter (N=15)

Energy expenditure (kJ/min)	Frequency	Percentage (%)
Low	02.00	13.33
Medium	12.00	80.00
High	01.00	06.67
Total	15.00	100.00
Mean		8.03
S.D		0.49

4.2.4 Discomfort rating

Body discomfort is one of the main causes in the development of musculoskeletal disorders. The mean body discomforts score of the respondents was of 69.97 with a standard deviation of 4.15 (Table 4.3). The discomforts score ranging from 65.15 to 73.82 was reported by 66.67 per cent of respondents. On fifth of the sample reported high body discomforts and relatively low body discomforts was reported by 13.33 percent of the sample.

The mean body discomfort score of the respondents was 61.6 while using tender coconut opener (Table 4.4). The discomfort score ranging from 56.09-67.11 was reported by 66.67 per cent of the respondents. One fourth of the sample reported relatively low body discomforts while

using tender coconut opener. Only 6.67 per cent of the sample reported relatively high body discomfort while using tender coconut opener.

Table 4.3 Distribution of the sample by body discomforts while operating coconut punch and splitter (N=15)

Body discomfort	Frequency	Percentage
Low (62-65.51)	2	13.33
Medium (65.51-73.82)	10	66.67
High	3	20.00
Total	15	100.00
Mean		69.67
S.D		4.15

Table 4.4 Distribution of the sample by body discomforts while operating tender coconut opener (N=15)

Body discomfort	Frequency	Percentage (%)
Low (50-56.09)	4	26.67
Medium (56.09-67.11)	10	66.67
High (67.11-71)	1	06.67
Total	15	100.00
Mean		61.6
S.D		5.51

The mean body discomfort score of the respondents was 63.4 while punching tender coconut in traditional method (Table 4.5). The discomfort core ranged from 51.54 to 75.26 was reported by 73.33 per cent of the respondents. Relatively high and low body discomfort was reported by equal percent of the respondents.

Table 4.5 Distribution of the sample by body discomforts while operating tender coconut opener (N=15)

Body discomfort	Frequency	Percentage (%)
Low (41-51.54)	2	13.33
Medium (51.54-75.26)	11	73.33
High (75.26-88)	2	13.33
Total	15	100.00
Mean		63.4
S.D		11.8

It was found that majority of the respondents experienced less body discomforts while punching tender coconut in traditional method compared to while coconut punch and splitter and tender coconut opener. The machine tool designed for tender coconut punching was not found suitable to use. The tender coconut punching is observed as one of the more strenuous work which requires application of force for cutting the coconut. The mean force exerted while punching tender coconut using coconut punch and splitter was 477.99 Newton's (Table 4.6). Eighty percent of the vendors have exerted a force 405.68 to 550.29 Newton. 13.33 per cent of the vendor's have exerted high force (i.e., 550.29 to 600.37 Newton's) and 6.67 % of the respondents have exerted the force between 333.54 and 405.68

Table 4.6 Distribution of the sample by body discomforts while operating tender coconut opener N=15

Body discomfort	Frequency	Percentage (%)
Low (333.54-405.68)	1	06.67
Medium (405.68-550.29)	12	80.00
High (550.29-600.37)	02	13.33
Total	15	100.00
Mean	477.99	
S.D	72.30	

The mean force exerted while punching tender coconut using tender coconut opener was 223.886 Newton's (Table 4.7). The standard deviation in the tender coconut vendors force exertion is 33.02. Eighty per cent of the vendors have exerted medium amount of force i.e., 190.86-256.91N. Three (3.33%) per cent of the vendors have exerted high force of 256.91 to 325.69 N and 6.67% of the respondents have spent the force between 170.69 and 190.86

The mean force exerted while punching tender coconut using tender coconut opener was 325.43 Newton's (Table 4.8). The standard deviation was 69.87. Relatively high (66.67%) per cent in the tender coconut vendors have exerted medium force i.e., 255.47 to 395.22 Newton's. Thirteen (13.33%) per cent of the vendors have excrete high force i.e., 395.22 to 437.53

Newton's and one fifth of the respondents have spent the force in between 196.2 and 255.47 Newton's.

Table 4.7 distribution of the sample by body discomforts while operating tender coconut opener N=15

Body discomfort	Frequency	Percentage (%)
Low (170.69-190.86)	1	06.67
Medium (190.86-256.91)	12	80.00
High (256.91-325.69)	2	03.33
Total	15	100.00
Mean	223.886	
S.D	33.02	

Table 4.8 distribution of the sample by body discomforts while operating tender coconut opener N=15

Body discomfort	Frequency	Percentage (%)
Low (196.2-255.47)	3	20.00
Medium (255.47-395.22)	10	66.67
High (395.22-437.53)	2	13.33
Total	15	100.00
Mean	325.34	
S.D	69.87	

The force exerted by the tender coconut vendors while punching with the coconut punch and splitter was higher. Between punching with tender coconut opener and traditional method of punching, punching with coconut demanded less force with respect to force tender coconut opener was found the best.

4.3 Development of Green Tender Coconut Splitter-cum-Punching Machine

The manual coconut cutter is an advanced method, which is to cut the coconut in an easy way of operation. This will reduce the human effort and avoid chances for accidents of the manual method of operation. It reduces the operational cost of the work. Comparing to the automatic method, this project is a very effective and advantageous method. This project is to saves more valuable time. In order to solve these problems, machine has been developed to cut the coconut and punch the coconut (Mownesh and Mehta, 2015). It is faster than the existing traditional method. Human effort is almost eliminated and also productivity is increased. The device can be easily assembled and dismantled. Spare parts (Bolts & Nuts) can be replaced with the use of simple tools. High efficiency compared to traditional method of punching and splitting. It is easy to operate with minimum skill level. Product cost is reasonably economical for tender coconut vendors. Handle is such that it can suit the operator to operate both sitting and standing positions.

4.3.1 Engineering parameter of green tender coconut

Some engineering properties of green tender such as size, sphericity, roundness, volume, surface area, density, coefficient of friction against different materials and compression test were studied for handling the tender. One hundred green tenders were randomly selected for the measurement of physical properties such as the shape, size, volume, density, surface area etc. The three principal dimensions were measured using a Vernier Calliper with an accuracy of 0.02 mm. Measurements of three mutually perpendicular axes were made: namely major, intermediate and minor diameters (Fig 4.4).

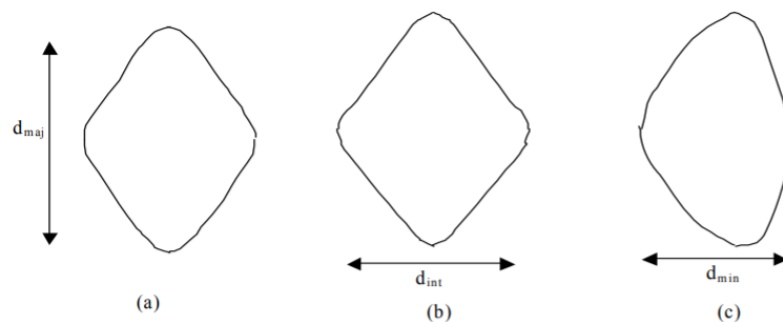


Fig.4.4 Selected principle diameter of green tender for measurement.

The principal dimensions, major, intermediate and minor areas were measured for one hundred seeds with a vernier caliper (Nagarajan. and Sundararajan. 2017). The results obtained are presented in Table 4.9. The values of the major diameter range from 21.99 cm to 15.50 cm with mean of 19.56 cm and standard deviation of 1.54 cm. The values of the intermediate diameter range from 17.92 cm to 12.35 cm, with mean value of 15.24 cm and standard deviation of 1.56 cm. The value of the minor diameter ranges from 12.44 cm to 7.40 cm, with mean value of 9.95 cm and standard deviation of 1.47 cm. It was observed that the intermediate diameter and the minor diameter varied significantly and different mean value and standard deviation value, hence the intermediate diameter is larger to the minor diameter comparatively. The major diameter and the minor diameter have high variability compared with other diameter. Table 4.9 presented the mean values of the three principal diameters. The principal dimensions of the green tender of 100 samples were used to compute the sphericity as shown in Table 4.9. The sphericity of the green tender varies from 0.87 to 0.60 with standard deviation of 0.06. The sphericity value indicates that the shape of the tender approximates that of a sphere because of the mean sphericity value is 0.73 with a very little deviation among the seeds. The volume of hundred tender measured by water displacement method. The volume ranges from 1293.41 cm³ to 823.05 cm³ with a mean volume of 1056.07 cm³ as shown in Table 1. The density of the samples ranges from 0.65 g/cm³ to 1.32 g/cm³ with a mean value of 0.92 g/cm³ as shown in Table 4.9.

Table 4.9 Measurement of engineering parameters of green tender coconut (N=100).

Sample	Diameters, cm				Sphericity	Weight, g	volume, cc	Density, g/cc
	Major	Intermediate	Minor	Geometrical mean				
1	17.60	17.46	10.81	14.92	0.85	1017.66	1293.41	0.79
2	20.67	14.58	9.82	14.36	0.69	945.03	1163.14	0.81
3	21.99	17.24	11.40	16.29	0.74	976.81	1052.04	0.93
4	18.68	13.53	9.54	13.41	0.72	959.65	1215.94	0.79
5	21.76	17.36	10.57	15.86	0.73	881.80	1140.64	0.77
6	18.53	14.51	9.37	13.60	0.73	934.61	1140.27	0.82
7	21.76	17.43	12.44	16.77	0.77	940.88	862.41	1.09
8	21.05	15.17	7.67	13.48	0.64	1000.89	1044.79	0.96
9	19.66	16.42	10.40	14.97	0.76	987.67	1066.67	0.93
10	19.05	17.38	9.11	14.45	0.76	869.26	1124.38	0.77
11	19.08	17.15	11.52	15.56	0.82	1004.57	1190.32	0.84
12	20.31	15.02	9.94	14.48	0.71	875.85	1163.53	0.75
13	19.00	14.75	8.11	13.15	0.69	861.23	1138.47	0.76
14	21.06	13.20	8.99	13.57	0.64	979.60	1135.15	0.86
15	19.89	14.56	10.02	14.26	0.72	1059.97	1040.00	1.02
16	21.88	15.61	9.91	15.01	0.69	1048.20	1229.20	0.85
17	18.99	17.49	10.73	15.28	0.80	848.85	916.92	0.93

18	17.72	15.25	11.42	14.56	0.82	913.15	987.94	0.92
19	20.82	17.58	9.25	15.02	0.72	833.61	1176.50	0.71
20	17.68	15.90	10.05	14.14	0.80	1087.75	1128.86	0.96
21	17.47	13.25	11.98	14.05	0.80	1047.75	1074.31	0.98
22	17.60	15.88	7.56	12.83	0.73	1007.16	866.13	1.16
23	17.42	13.03	11.08	13.60	0.78	836.61	1282.17	0.65
24	17.37	14.12	11.77	14.24	0.82	974.17	1188.47	0.82
25	18.77	17.86	11.55	15.70	0.84	973.68	892.60	1.09
26	20.41	13.81	9.81	14.04	0.69	926.22	984.72	0.94
27	21.95	14.11	10.98	15.04	0.69	988.71	905.53	1.09
28	18.74	15.06	8.65	13.47	0.72	1096.04	939.11	1.17
29	20.11	17.09	10.19	15.19	0.76	963.16	1005.45	0.96
30	21.66	12.49	11.17	14.46	0.67	951.36	936.89	1.02
31	18.21	17.43	12.43	15.80	0.87	931.02	1135.39	0.82
32	21.81	14.03	10.08	14.56	0.67	872.74	837.66	1.04
33	18.96	12.75	7.93	12.42	0.66	853.07	1218.91	0.70
34	17.98	13.14	7.64	12.18	0.68	1049.38	908.47	1.16
35	21.97	13.44	10.49	14.58	0.66	1071.37	919.90	1.16
36	17.55	12.35	10.58	13.19	0.75	953.86	1004.73	0.95
37	21.19	17.15	9.20	14.95	0.71	871.55	1058.00	0.82
38	21.81	13.86	10.05	14.48	0.66	998.66	1208.30	0.83
39	20.05	14.38	11.31	14.83	0.74	1092.65	1276.46	0.86
40	19.50	12.96	8.10	12.70	0.65	852.85	981.82	0.87
41	21.62	16.02	9.30	14.77	0.68	963.88	932.23	1.03
42	21.96	13.90	7.63	13.25	0.60	867.16	1250.58	0.69
43	19.98	16.02	8.49	13.96	0.70	894.38	1022.64	0.87
44	18.70	13.68	12.10	14.57	0.78	846.96	1229.58	0.69
45	21.19	14.57	9.98	14.55	0.69	857.17	968.66	0.88
46	19.64	13.29	11.53	14.44	0.74	947.50	950.85	1.00
47	19.12	13.43	12.15	14.61	0.76	991.83	1163.32	0.85
48	18.90	12.61	10.89	13.74	0.73	1049.67	1076.07	0.98
49	20.42	17.68	8.28	14.41	0.71	1067.59	1104.33	0.97
50	18.70	15.19	8.59	13.46	0.72	1055.18	948.70	1.11
51	19.01	16.59	8.19	13.72	0.72	835.01	1168.81	0.71
52	17.42	17.38	7.90	13.37	0.77	956.02	1220.19	0.78
53	21.13	15.46	9.59	14.63	0.69	840.43	869.98	0.97
54	21.86	14.32	11.15	15.17	0.69	827.65	928.53	0.89
55	18.83	15.01	8.54	13.41	0.71	852.42	1261.87	0.68
56	19.04	15.27	9.08	13.82	0.73	967.06	1097.97	0.88
57	19.19	15.52	9.69	14.24	0.74	912.76	1213.13	0.75
58	20.42	14.66	7.73	13.23	0.65	1027.94	883.69	1.16
59	21.97	17.92	9.53	15.54	0.71	997.16	1010.74	0.99
60	21.74	13.92	12.10	15.41	0.71	1037.47	1011.12	1.03
61	19.90	16.18	10.64	15.08	0.76	1055.01	843.22	1.25
62	18.14	17.32	11.93	15.54	0.86	937.72	848.99	1.10
63	17.53	15.39	8.55	13.21	0.75	845.04	904.57	0.93
64	20.76	13.06	10.10	13.99	0.67	1003.53	1279.26	0.78
65	18.51	15.92	8.21	13.43	0.73	1036.12	937.67	1.10
66	17.43	14.90	10.32	13.89	0.80	921.39	1050.77	0.88
67	20.41	14.15	12.05	15.16	0.74	997.90	1080.62	0.92
68	17.69	16.21	8.76	13.59	0.77	853.16	1065.36	0.80
69	19.78	16.47	9.90	14.78	0.75	1036.71	1045.32	0.99
70	19.74	13.83	8.62	13.30	0.67	897.89	1257.11	0.71

71	17.42	17.67	9.80	14.45	0.83	911.73	1232.17	0.74
72	21.75	16.49	7.68	14.02	0.64	845.00	864.70	0.98
73	21.04	14.13	11.94	15.26	0.73	841.11	986.17	0.85
74	18.21	16.81	12.08	15.46	0.85	937.83	879.04	1.07
75	19.82	14.99	9.89	14.32	0.72	1095.48	828.32	1.32
76	18.46	15.06	7.79	12.94	0.70	890.06	1194.49	0.75
77	17.93	13.67	8.36	12.70	0.71	896.29	857.03	1.05
78	17.33	15.87	9.88	13.95	0.81	984.03	1034.18	0.95
79	21.12	16.62	11.08	15.72	0.74	832.01	1161.10	0.72
80	19.20	17.69	7.76	13.81	0.72	924.75	1073.75	0.86
81	21.80	13.45	12.36	15.36	0.70	999.38	1038.56	0.96
82	18.20	15.29	9.11	13.64	0.75	985.94	1167.11	0.84
83	17.32	13.77	12.36	14.34	0.83	899.66	993.85	0.91
84	21.52	13.63	9.56	14.10	0.66	961.44	1200.60	0.80
85	17.31	14.30	11.91	14.34	0.83	1051.87	1221.23	0.86
86	19.67	16.83	7.74	13.69	0.70	913.98	965.24	0.95
87	19.07	14.88	11.27	14.73	0.77	831.75	1172.76	0.71
88	21.23	15.30	10.76	15.17	0.71	947.02	970.42	0.98
89	19.11	14.97	9.84	14.12	0.74	922.62	823.05	1.12
90	20.30	16.80	11.54	15.79	0.78	963.77	1027.60	0.94
91	19.70	12.79	11.32	14.59	0.68	1037.93	901.97	1.15
92	19.69	17.15	10.76	15.37	0.78	931.76	1229.17	0.76
93	18.99	13.86	10.22	13.90	0.73	880.83	987.55	0.89
94	15.50	15.28	12.15	14.77	0.85	1065.17	1174.89	0.91
95	18.51	15.99	9.31	14.02	0.76	1094.21	921.07	1.19
96	18.94	14.21	8.23	13.04	0.69	831.78	1169.09	0.71
97	19.56	15.96	11.63	15.37	0.79	829.04	1079.37	0.77
98	19.93	17.67	7.40	13.76	0.69	987.80	905.14	1.09
99	17.40	17.15	7.50	13.08	0.75	1029.22	892.80	1.15
100	21.68	13.82	8.64	13.74	0.63	939.58	1192.81	0.79
Max	21.99	17.92	12.44	16.77	0.87	1096.04	1293.41	1.32
Min	15.50	12.35	7.40	12.18	0.60	827.65	823.05	0.65
Avg	19.56	15.24	9.95	14.31	0.73	949.82	1056.07	0.92
SD	1.54	1.56	1.47	0.90	0.06	78.22	132.69	0.15

4.3.2 Measurement of anthropometric dimensions of male farm workers

About 108 tribal have been selected for the measurement of selected anthropometric dimensions to develop the green tender coconut splitter cum punching machine. There are 12 body dimensions have been identified for the development of green tender splitter cum punching machine. The identified anthropometric dimension have been statistically analyzed for their mean, standard deviation, coefficient of variance, standard error, along with 5th and 95th percentile. Minimum and maximum values of particular dimension have also been recorded. The details of each measured dimensions discussed as follows:

Weight

It was found that the maximum weight of selected person of Bastar was found to be 80 whereas minimum weight found to be was 47. The mean value of weight of was calculated as 66.73 with the SD of 6.95 as shown in Table 4.10. Statistical analysis suggested that 5th percentile is 53.90 and 95th percentile value was 75.05 also CV was about 117%.

Age

It was found that the maximum age of selected person of Bastar was found as 29 whereas minimum age was 22. The mean value of age of was calculated as 26.33 with the SD of 2.06 as shown in Table 4.10. Statistical analysis suggested that 5th percentile is 22.95 and 95th percentile value was 29 whereas the CV was about 7.83%.

Iliocrystale height

It was found that the maximum Iliocrystale height of selected person of Bastar found to be 103 cm whereas minimum Iliocrystale height found to be 92 cm. The mean value of Iliocrystale height of was calculated as 97.86 cm with the SD of 2.89 cm as shown in Table 4.10. Statistical analysis suggested that 5th percentile is 93cm and 95th percentile value was 102 cm also CV was about 2.97 %.

Elbow height

It was found that the maximum elbow height of selected person of Bastar was found to be 117 cm whereas minimum elbow height found to be was 98 cm. The mean value of elbow height of was calculated as 107.63 cm with the SD of 5.27cm as shown in Table 4.10. Statistical analysis suggested that 5th percentile is 99.9 cm and 95th percentile value was 117 cm also CV was about 4.89%.

Waist Circumference

It was found that the maximum waist circumference of selected person of Bastar was found to be 94 cm whereas minimum waist circumference found to be was 52 cm. The mean value of waist circumference of was calculated as 62.46 cm with the SD of 5.46 cm as shown in Table 4.10. Statistical analysis suggested that 5th percentile is 54 cm and 95th percentile value was 66 cm also CV was about 8.75 %.

Biacromial breadth

It was found that the maximum Biacromial breadth of selected person of Bastar was found to be 53cm whereas minimum Biacromial breadth found to be was 37 cm. The mean value of Biacromial breadth of was calculated as 43.16 cm with the SD of 3.16 as shown in Table 4.10.

Statistical analysis suggested that 5th percentile is 40.95 cm and 95th percentile value was 45.0 cm also CV was about 7.34 %.

Elbow width

It was found that the maximum elbow width of selected person of Bastar was found to be 49 cm whereas minimum elbow width found to be was 37cm. The mean value of elbow width of was calculated as 41.10 cm with the SD of 3.31cm as shown in Table4.10. Statistical analysis suggested that 5th percentile is 37cm and 95th percentile value was 48.05 cm also CV was about 7.86%.

Acromion height

It was found that the maximum acromion height of selected person of Bastar was found to be 150 cm whereas minimum acromion height found to be was 130 cm. The mean value of acromion height of was calculated as 140.68 cm with the SD of 4.10 cm as shown in Table4.10. Statistical analysis suggested that 5th percentile is 134.9cm and 95th percentile value was 148.05cm also CV was about 2.09%.

Grip diameter

It was found that the maximum grip diameter of selected person of Bastar was found to be 9 cm whereas minimum grip diameter found to be was 5 cm. The mean value of grip diameter of was calculated as 7.4 cm with the SD of 1.25 cm as shown in Table4.10. Statistical analysis suggested that 5th percentile is 6cm and 95th percentile value was 9 cm also CV was about 16.91%.

Hand length

It was found that the maximum hand length of selected person of Bastar was found to be 19cm whereas minimum hand length found to be was 18cm. The mean value of hand length of was calculated as 18.33cm with the SD of 0.45 cm as shown in Table4.10. Statistical analysis suggested that 5th percentile is 18cm and 95th percentile value was 19cm also CV was about 2.48%.

Hand width

It was found that the maximum hand width of selected person of Bastar was found to be 12cm whereas minimum hand width found to be was 10 cm. The mean value of hand width of was calculated as 10.93cm with the SD of 0.84cm as shown in Table4.10. Statistical analysis suggested that 5th percentile is 10cm and 95th percentile value was 12.0 cm also CV was about

7.69%. The summarized average value of measured anthropometric dimensions have been presented in 4.10

4.3.3 Measurement of anthropometric dimensions of female farm workers

Iliocrystale height

It was found that the maximum Iliocrystale height of selected person of Bastar was found to be 89 whereas minimum Iliocrystale height found to be was 80 cm. The mean value of Iliocrystale height of was calculated as 83.4cm with the SD of 2.21cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 80cm and 95th percentile value was 87 cm also CV was about 2.65%.

Table 4.10 Statistical parameters of selected anthropometric dimension of male farm workers of Bastar

No.	Parameters	Mean	Min	Max	SD	CV %	SE	5 th	95 th
1.	Iliocrystale height	97.86	92	103	2.89	2.97	0.37	93	102
2.	Elbow height	107.7	98	117	5.27	4.89	0.37	99.9	117
3.	Waist Circumference	62.46	52	94	5.46	8.75	0.70	54	66
4	Biacromial breadth	43.16	37	53	3.16	7.34	0.40	40.95	45
5	Elbow width	41.1	37	49	3.31	7.86	0.42	37	48.05
6	Acromion height	141.4	130	150	4.10	2.09	0.53	134.9	148.05
7	Grip diameter	7.4	5	9	1.25	16.91	0.16	6	9
8	Hand length	18.33	18	19	0.45	2.48	0.05	18	19
9	Hand width	10.93	10	12	0.84	7.69	0.10	10	12
10	Weight	66.21	47	80	6.95	11.0	0.89	53.9	75.05
11	Age	26.33	22	29	2.06	7.83	0.26	22.95	29

Elbow height

It was found that the maximum elbow height of selected person of Bastar was found to be 99cm whereas minimum elbow height found to be was 92cm. The mean value of elbow height of was calculated as 95.62cm with the SD of 1.73cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 92 cm and 95th percentile value was 99 cm also CV was about 1.81%.

Waist Circumference

It was found that the maximum waist Circumference of selected person of Bastar was found to be 91cm whereas minimum waist Circumference found to be was 82cm. The mean value of waist Circumference of was calculated as 86.35 cm with the SD of 3.16cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 82cm and 95th percentile value was 91cm also CV was about 3.66%.

Biacromial breadth

It was found that the maximum Biacromial breadth of selected person of Bastar was found to be 39cm whereas minimum Biacromial breadth found to be was 37 cm. The mean value of Biacromial breadth of was calculated as 37.82cm with the SD of 0.930cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 37 cm and 95th percentile value was 39 cm also CV was about 2.46%.

Elbow width

It was found that the maximum elbow width of selected person of Bastar was found to be 42cm whereas minimum elbow width found to be was 38cm. The mean value of elbow width of was calculated as 40.77cm with the SD of 1.25cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 38cm and 95th percentile value was 42cm also CV was about 3.06%.

Acromion height

It was found that the maximum acromion height of selected person of Bastar was found to be 128cm whereas minimum acromion height found to be was 122cm. The mean value of acromion height of was calculated as 124.27cm with the SD of 2.16cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 122cm and 95th percentile value was 128cm also CV was about 1.73%.

Grip diameter

It was found that the maximum grip diameter of selected person of Bastar was found to be 6cm whereas minimum grip diameter found to be was 5 cm. The mean value of grip diameter of was calculated as 5.3cm with the SD of 0.46cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 5cm and 95th percentile value was 6 cm also CV was about 8.75%.

Hand length

It was found that the maximum hand length of selected person of Bastar was found to be 17cm whereas minimum hand length found to be was 16cm. The mean value of hand length of was calculated as 16.72cm with the SD of 0.45cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 16cm and 95th percentile value was 17cm also CV was about 2.70%.

Hand width

It was found that the maximum hand width of selected person of Bastar was found to be 9cm whereas minimum hand width found to be was 8 cm. The mean value of hand width of was calculated as 8.5cm with the SD of 0.50cm as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 8cm and 95th percentile value was 9 cm also CV was about 5.95%

Weight

It was found that the maximum weight of selected person of Bastar was found to be 49 whereas minimum weight found to be was 41. The mean value of weight of was calculated as 46.05 with the SD of 2.19 as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 41 and 95th percentile value was 49 also CV was about 4.76%.

Age

It was found that the maximum age of selected person of Bastar was found to be 45 whereas minimum age found to be was 26. The mean value of age of was calculated as 37.52 with the SD of 6.13as shown in Table 4.11. Statistical analysis suggested that 5th percentile is 26 cm and 95th percentile value was 45cm also CV was about 16.33%.

Table 4.11 Statistical parameters of selected anthropometric dimension of female farm workers of Bastar

No.	Parameters	Mean	Min	Max	SD	CV %	SE	5 th	95 th
1.	Iliocrystale height	83.4	80	89	2.21	2.65	0.35	80	87
2.	Elbow height	95.62	92	99	1.73	1.81	0.27	92	99
3.	Waist Circumference	86.35	82	91	3.16	3.66	0.50	82	91
4	Biacromial breadth	37.82	37	39	0.930	2.46	0.14	37	39
5	Elbow width	40.77	38	42	1.25	3.06	0.19	38	42
6	Acromion height	124.27	122	128	2.16	1.73	0.34	122	128

7	Grip diameter	5.3	5	6	0.46	8.75	0.073	5	6
8	Hand length	16.72	16	17	0.45	2.70	0.071	16	17
9	Hand width	8.5	8	9	0.50	5.95	0.08	8	9
10	Weight	46.05	41	49	2.19	4.76	0.34	41	49
11	Age	37.52	26	45	6.13	16.33	0.96	26	45

4.3.4 Design consideration for green tender coconut splitter cum punching machine

The machine is to be designed for improve the quality of cutting the coconut with least efforts and less man power. It should be able to reduce the chance of accident while cutting the coconut. It could be portable. Minimum effort must be required to changing of cutting blades and drill tool frequently. It must be required less effort as compared to other cutting process of coconuts. The machine would be used to cut and punch the tender. The idea is to apply the pressure to cut and punch the green coconuts. Initially coconut is placed in the circular box. After that lever is attached to closed coil .The pressure is applied on the lever to punch the coconut (Rajanikanth and Reddy, 2015). After removing pressure lever comes to original position by tension of spring. After removing the water coconut is placed in that rectangular tray. Apply the pressure on the lever to cut the coconut by the use of knife. It is very simple operation. It does not have more skill to cut the coconut. To perform the mentioned action following component have been developed,

1. Height of machine: The height of the machine is designed on the basis of elbow height of selected population of Bastar. The machine height is selected 1 meter from that 72 cm is standing height and rest is installed in ground.

2. Width of machine: The width of machine is designed on the basis of elbow width of selected population of Bastar people. The machine width is taken 60cm.

3. Length: The length of the machine is taken on the basis of anthropometric dimension of Bastar.

4. Handle: The handle for catching and splitting of coconut is around 30cm.

6. Material: the stainless steel materials are used for design of coconut cutting machine.

7. Knife: The blade length is used for splitting of coconut. The blade length is 60cm and blade is made up of steel. The thickness of the blade has been taken 8 mm.

8. Weight: The weight of machine is 20 kg. So that anyone can lift the machine from one place to another place.

9. Punching tool: Designed based on the average Tender coconut dimensions by measuring the length from top of Tender coconut to the water level its measures to be average of 5cm. So by giving 2 cm extra length to the punching bit a total length of 7 cm (70 mm) is made. In the punching bit 20 mm provision is provided to remove the dust particle during punching of a Tender coconut. The punching material selected is stainless Steel as it has corrosive resistant properties and has good strength. Average depth of shell of coconut from outer surface was found between 70 to 100 mm and the diameter of straw generally and radically available was 6 to 8 mm therefore a punch of 160 mm and length 12 mm diameter was selected. One end of tool was threaded up to 25 mm length to fix it securely in the holder and other end was pointed up to 30 mm length. As the tool had to work in contact with tender coconut water, stainless steel material was used to prevent corrosion.

10. Tray and Cutting Unit: The tray is provided at down of the machine for collecting the coconut after cutting the coconut.

11. Splitting Tool: It is used to split the coconut into two halves. It is made up of mild steel. The thickness of this tool is 5 cm. A small rod is welded at one end for the movement control of this tool.

12. Lever: This is the main working part of this machine which is made up of mild steel. The diameter of the lever is 2 cm. The length of the lever is 90 cm. The distance between the point at which the punching tool is connected and the point at which effort is applied is 70 cm.

13. Guide: A Metal Guide is used to restrict the motion of the punching tool.

14. Frame: Frame is a structure of machine on which the other components are placed. It is made up of iron.

Cost of fabrication: The total fabrication cost of machine found to be about Rs. 8560/- per unit which includes material and fabrications charges. Institute overhead charges and other charges have been neglected in this investigation.

The construction steps for our coconut water extracting machine are as follows: The frame of machine is made up of mild steel.– The punching tool is connected to the lever.– The punching tool is made sharp pointed at one end– and is made up of mild steel. The movement of tool is guided by the metal guide.– The splitting tool is also made up of mild steel.– The splitting tool is placed separately on the– working bed. To place the coconut on the bed a holding device is– used. The working principle of the coconut water extracting machine is as follows: The coconut is kept on the holding device.– The punching tool will be moved upward and– downward as per the need with the help of liver. While making the hole in the coconut, move the– lever downward. This will make a hole on the coconut. Now move the lever in upward direction in order to– remove the punching tool from coconut. Now the coconut is ready to serve.– In case of cutting the coconut into two halves, the– splitting tool will be used.



Fig 4.5 Coconut splitter cum punching machine

4.4 Feasibility Testing of Green Tender Splitter cum Punching Machine

Sample: Three different samples of different sizes are selected for the experimentation. The principle diameters of the fruit was 19.22 ± 0.88 mm, 15.91 ± 0.58 mm and 15.2 ± 0.47 mm, with an weight of 0.85 ± 0.15 kg, 1.34 ± 0.15 kg and 1.67 ± 0.15 kg respectively.

Force: The force to make a punching and splitting in tender coconut is observed to be 127 N and 543 N.

Nut cut per hour: It is estimated by measuring time of 5 nuts and 10 nuts randomly. It is observed that splitting and serving the tender takes about 49 sec for each coconut while splitting the tender takes 12 sec only. Rest of the time consumed in picking the coconut in choice and handling. It is expected that around 40-45 nuts in an hour could be serve to customers. About 2-5 minutes work rest cycle has also been included operation. Similarly, punching takes only 5 sec.

4.4.1 Ergonomic evaluation of the developed tender coconut splitter cum punching machine

The performance of selected coconut cutting machine has been judge through HR, OCR, BPDCR and feedback. Further their performance has been compared based on the number of coconut cut per minute or punching (in case coconut water). The cutting direction of the coconut was shown to play an important role on the quality of cutting. It was clear that direction of placing the coconut knife parallel to the coconut did not successfully cut the coconut into half. The optimal knife angle was set up at 45 degree. However, if the direction of placing the coconut fibre was perpendicular to knife edge, the fruit was absolutely cut without any damage at any speed of the pressing unit. The pressing unit speed insignificantly affected the cutting quality. The splitting time for the equipment was identified to an average of 16 sec. Similarly the punching time was 8 sec.

It was observed that the time for cutting, piercing and dewatering was varied due to moisture content. The time increased gradually when moisture content decreased. This was due to the increase in firmness of husk due to loss of moisture. The moisture content of the outer part of two coconuts varieties were measured at different storage duration. Moisture content of the tall variety found to be greater than the dwarf variety. A decreasing trend of moisture content

with storage duration was observed for both tall and dwarf varieties. It was also observed that the mean energy expenditure found to be 7.20 kJ/min using developed machine while 8.03 kJ/min in conventional way. It was experienced that punching took little higher energy than the conventional but dressing time and effort was not required before punching as in conventional methods. However, experienced vendors were found little difficulties and feel comfortable to operate machine. It was found that the physiological cost of work while punching tender coconut with the coconut punch and splitter was highest (35.96). In case of traditional method of cutting tender coconut physiological cost of work was less.

Perceived exertion of the respondents while performing tender coconut punching in traditional method was relatively lower than coconut punch and splitter and tender coconut opener. The two tools were not found user friendly tools. The design was not as per the requirements of the user. The drudgery was more while punching tender coconut with tender coconut opener. Punch tender coconut with the coconut punch and splitter was found with less drudgery than the traditional method of punching. The lever mechanism used in the might have contributed for the reduction in the drudgery.

It was found that majority of the respondents experienced less body discomforts while punching tender coconut in traditional method compared to while using coconut punch and splitter and tender coconut opener. The machine/tool designed for tender coconut punching was not found suitable to use. The force exerted by the tender coconut vendors while punching with the coconut punch and splitter was higher. Between punching with tender coconut opener and traditional method of punching, punching with coconut opener demanded less force with respect to force tender coconut opener was found the best. Significant mean differences in the ergonomics parameters while punching tender coconut by traditional method and by using punch cum splitter machine and tender coconut opener. Musculoskeletal discomforts in neck, shoulder, upper limbs and back were treated as dependent variables. None of the independent variable was found having significant correlation with the perception of musculoskeletal discomforts in neck, holder, upper limb and back. There was a highly significant mean difference ($P = <.0001$) in the energy expenditure by vendors while punching tender coconut using coconut punch and splitter, tender opener and traditional method.

Further to understand the significant mean difference pair wise mean comparisons were computed. With reference to energy expenditure, the vendor spent relatively more energy while operating coconut punch and splitter followed by tender coconut opener and traditional method. Highly significant mean difference in energy expenditure ($P = <.0001$) was found between coconut punch and splitter and tender coconut opener while punching tender coconut. Highly significant mean difference ($P = <.0001$) in energy expenditure was found between coconut punch and splitter and traditional method of opening tender coconut using a hand sickle was found. Highly significant mean difference ($P = <.0001$) was observed in energy expenditure between tender coconut opener and traditional method of punching tender coconut.

With reference to physiological cost of work, the vendors have experienced relatively high physiological cost of work while operating coconut punch and splitter followed by tender coconut opener and traditional hand method. Highly significant mean difference in physiological costs of work ($P = <.0001$) was found between coconut punch and splitter and tender coconut opener. Every tool differed significantly with other two tools on physiological cost of work. Physiological cost of work was relatively less in traditional method of cutting and punching tender coconut. Highly significant mean difference ($P = <.0001$) in physiological cost of work was found between coconut punch and splitter and traditional method of opening tender coconut using a hand sickle. Highly significant mean difference ($P = <.0001$) was observed in physiological cost of work between tender coconut opener and traditional method of punching tender coconut.

Injury: No injury has been recorded during pilot run of machine.

Performance evaluation

Twelve subjects were selected to performed operation with developed machine to observe HR, OCR and EER during the splitting cum punching operation. The subject population was considered the 60:40 ratio of male and female respectively. The cutting time of 10 coconuts of each variety were taken and used for performance evaluation. It was 19.8 and 16.8 seconds for tall and dwarf variety respectively when done manually. However, it was 18.6 and 15.6 seconds for tall and dwarf variety respectively. Minimum cutting time observed was 9.12 and 8.36 seconds for long and dwarf variety when done manually. However it was 8.16 and 7.22 seconds

for equipment. Time consumed by the machine was observed to be lesser with respect to the manual operation. Time consumed on dwarf variety was observed to be lesser than the time consumed by longer variety. It may be due to the hardy structure of the long variety coconut. A trend of increasing cutting time with the storage duration was observed for both of the varieties. This may be due to the decreasing moisture content and loss in firmness of the coconut outer surface.

The developed machine is able to punch the hole in tender coconut for sipping the water whereas it cuts the coconut into two halves to get coconut meat. The punching force observed to be about 178N whereas cutting of green tender demands 645N. Cutting and dewatering was done on 30 coconuts of both the varieties with varied storage period .Time consumed for the same was measured. For both of the varieties, time taken by the equipment was less than that of the manual operation. It may be due to the saved time during dewatering of the coconut in the equipment. The mean time taken for punching and splitting a tender coconut was found to be 8.16 seconds with a SD of the respondents 20%) took up to 5.17 seconds. Relatively more number of vendors (66.67%) took 5.18 seconds to 10.34 seconds. Only 13.33 took more than 10.35 seconds for splitting and punching a tender coconut.

Table 4.12: Operational performance of Green tender coconut splitter cum punching machine with different subjects

Subjects	Heart rate, bpm	OCR, l/min	EER, kJ/min
S1	100	0.46	7.18
S2	90	0.35	5.59
S3	91	0.36	5.75
S4	98	0.44	6.86
S5	94	0.39	6.23
S6	90	0.35	5.59
S7	92	0.37	5.91
S8	89	0.33	5.43
S9	92	0.37	5.91
S10	88	0.32	5.27
S11	100	0.46	7.18
S12	97	0.43	6.70
Mean	93	0.38	6.13
Max.	100	0.46	7.18
Min.	88	0.32	5.27

Table 4.13: Summarized operational performance of Green tender coconut splitter cum punching machine

SN	Parameters	Green tender coconut splitter cum punching machine
1	Heart rate, bpm	93
2	Oxygen consumption rate, l/min	0.38
3	Energy consumption rate, kJ/min	6.13
4	BPDCR	4
5	Average cutting/punching time	7 sec / 3 sec

Comparison with conventional methods

- 1) Less effort is required to perform the whole operation of punching the hole in the coconut.
- 2) No skilled person is required to perform operation.
- 3) Causes of accidents during the operation are completely eliminated.
- 4) Task of vendor or seller becomes easy.
- 5) As sell increases, profit for vendor will increase.
- 6) Waiting time for customer is reduced.
- 7) With the help of this machine, new entrepreneur can easily start his business.

Applications:

- 1) This machine can be set up in shop.
- 2) It can be used by street side hawkers.
- 3) It can be used in farms, houses etc.

CHAPTER-V

SUMMARY AND CONCLUSIONS

Tender coconut is consumed either for water or meat. Every consumer cannot cut and punch tender coconut for consuming. The consumer has to depend on a vendor for cutting and punching a tender coconut. Dependency on a skilled vendor to cut and punch the tender coconut can be of the limiting factors for consuming coconut water. Due to the technique essential to cut and punch the tender coconut, the business is centered on male street vendors who possess skill in opening a tender coconut. Traditional method of tender coconut cutting and punching has high risk of injuries and requires a lot of effort. As the conventional method of punching tender coconut is inappropriate few designs for manually and mechanically operating tender coconut punching tools were proposed. Earlier researchers have designed few power operated and manually operated machines for extracting coconut water available for southern part of India. As on date there were limited suitable manually operated tender coconut punching tools available in the local market of Bastar. This is one of the major reasons that the vendors still continue the strenuous operation. Tender coconut punching is a labor intensive work which involves work which involves a lot of repletion and force application.

Both conventional method and existing machines require a lot of force and the tender coconut vending itself is a respective task. Therefore there is a need for careful study of the existing tools for designing a new coconut punching tool for safety and to lessen effort in cutting a tender that can also be utilized by common consumer and commercial vendor. Therefore the study was undertaken to explore the various markets and identify the available tender coconut punching tools and to produce design changes and redesign the tender coconut punching tool that is economical and efficient.

A survey was conducted to explore the availability of different manually operated tender coconut punching tools available in local and online markets for Bastar region. Further, some selected existing machines designed for coconut cutting has been investigated and compared with traditional method of cutting. This suggests a base for recommending design new green tender coconut splitting cum punching machine for the tribal people of Bastar. Before designing new one, selected existing machinery thoroughly investigated for adaptability in Bastar. Once

ergonomical assessments of selected machinery were done, it determined that selected machines were not suitable for Bastar tribal due to difference in anthropometric dimension. Following conclusions were drawn from the study;

1. The people in the middle age group (30-40 years) were involved mostly in tender coconut vending business. It was observed that tender cutting was preferred by male members of family and coconut vending was taken up as income earning activity mostly by men when compared to women. It was observed that as daughter none of the female was involved in the tender coconut vending business, but as mothers and grandmothers female member in the family took up tender coconut vending as income generating activity. Women were found taking up equally strenuous activities on par with their male counterparts as income earning activities when the circumference demand.
2. The prevalence of small families was observed among tender coconut vendors. However, no specific trend was observed when an opportunity to take up gainful employment members of the family took up it and contributed towards family income. Tender coconut vending business might be a prospective source of income as vendors who entered in the business were found to stick on to the business for a long period. On an average tender coconut vendors were earning monthly profit of about Rs. 8000/-.
3. Time taken for cutting and punching tender coconut were found to be exclusively subjective. The experience of vendor and the age of tender coconut were some of the factors that affect the time taken for cutting and punching tender coconut. Majority of the tender coconut vendors were experiencing moderate level of musculoskeletal discomforts in neck, pain in the shoulder and stiffness in the shoulder. The socio economic status, long working hours, experience in the tender coconut vending business and number of coconuts sold in a day had no significant correlation with musculoskeletal discomforts in neck, shoulder, upper limb and back.
4. The energy expenditure rate estimated to be 5.13, 11.26 and 9.34 kJ/min for machine 1, machine 2 and Machine 3 respectively. And, all three methods differed significantly.
5. Traditional method of punching tender coconut by using a hand sickle was found less energy consuming since vendors are habituated. Vendors were relatively comfortable with traditional method of cutting and punching tender coconuts.

6. Out of the three methods vendors perceived comparatively less physical exertion while using traditional method. Both tools selected were equally causing body discomforts while operation. However, all three methods graded as high workload from ergonomics viewpoint.
7. On the basis of anthropometric observations of Bastar farmers, a coconut splitting cum punching machine was developed successfully. The technical specification of green tender coconut splitting cum punching machine found to be as total height of the machine is 75cm, width of the machine 20 cm, length of the machine 40 cm, handle length 45 cm, thickness of the blade 8 mm and diameter for coconut holding 17cm.
8. The workload found to be in 'light' with the use of developed green tender splitting cum punching machine. Punching tender coconut was found less drudgery prone and comfortable in new machine and vendors relatively experienced less drudgery with this machine.
9. The mean HR, OCR and EER values were found to be 93 bpm, 0.38 l/min and 6.13 kJ/min respectively for developed green tender coconut splitting cum punching machine for tribal of Bastar.
10. It is expected that around 40-45 nuts in an hour could be serve to customers. About 2-5 minutes work rest cycle has also been included operation. Similarly, punching takes only 5 sec. There was no significant mean difference between green tender coconut splitting cum punching machine and traditional method in the body discomfort.
11. The research revealed that the force exertion for punching tender coconut by three methods differed significantly. Punching tender coconut by using new intervention was found comfortable and vendors relatively exerted less force while using tender coconut opener with reference to force exertion.

Implication of the study

The results of the study can serve as base for working on new designs for tender coconut punching tools. The tool designed can reduce the drudgery involved in punching tender coconut. The convenient tool can be of great help to women to take up tender coconut vending business. The tool can be used at household level by consumers.

Areas of future research: The ergonomic evaluation to understand the design features of designed tender coconut punching tools can be taken up to propose modifications.

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