DESIGN AND DEVELOPMENT OF A CONCEPTUAL
TEA LEAF HARVESTING MACHINE

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Abstract
Tea cultivation in India has a long history of application in traditional system of medicine as well as for consumption. India is cultivating and consuming for thousands of years. Commercial production of tea in India started with the arrival of English East India Company. Tea is a major beverage in India. It is considered as the second cheapest drink after water. India and China are the largest producers as well as the consumers of tea. Tea manufacturing is done by processing the tea leaves. The tea leaves are plucked from the plant and take to the factory where it is processed. For good quality tea only the buds including the third leaf has to be plucked and processed. The shortage of laborers and the increase in wages made the management to think of an alternate method of harvesting the tea leaves. This resulted in the mechanization of tea leaves harvesting.

Research has to be conducted among the tea leaf harvesting people to understand more about the current scenario. Research was carried out through product study, market study, literature review, interviews, user study, ethnographic research etc. Quality function deployment (QFD) was prepared where the customer voice were converted into technical voice. Detailed product design specification (PDS) was created as per the data’s from QFD. Mind mapping was used to create ideas. Five Concepts were generated using the prepared PDS. Using the weighted ranking method, a concept was selected which has most of the qualities which the QFD demands.

The final concept was selected with the help of weighted ranking method and the detailed drawings were made. Mock-up model of size 1:1 was made. The validation of the product has been carried out. The mock up model was satisfying with for most of the designers and customers. The user requirements like light weight, proper vision of the process, easy cleaning and servicing were met through this study. From the study, the proposed concept appears to show a potential saving of 15% in weight, and should therefore likely find acceptance in the field.

1. INTRODUCTION
Tea cultivation in India has a long history in application of traditional system of medicine as well as for consumption. India is cultivating and consuming for thousands of years. Commercial production of tea in India started with the arrival of English East India Company[7]. Tea is a major beverage in India. It is considered as the second cheapest drink after water. India and China are the largest producers as well as the consumers of tea. 70% of tea produced in India is consumed in India itself. Tea is grown in places having rain in most of the years. Hilly terrain is preferred for tea plantation since water will flow away. Tea is prepared by steeping processed leaves or buds in water.

Tea manufacturing is done by processing the tea leaves. The tea leaves are plucked from the plant and takes to the factory where it is processed. For good quality tea only the buds including the third leaf has to be plucked and processed. Plucking of tea leaves are mainly done by women. An experienced person will pluck around 40kg of tea leaf per day. Tea leaves harvesting require sharp eyes and quick hands. These leaves are collected in a place and are taken to the factory where the processing is done.

Migration of the new generation to other fields leads to shortage of labor in tea harvesting sector. Now this has become a major problem for tea plantations. Management is not able to supply adequate number of laborers for leaf plucking. These plantations are bearing big loss since they are unable to harvest the tea leaves on time.
while the export of tea till October 2010 is estimated at 29.64 Metric kg valued at Rs 133.93 per kg [10]. Since India is one of the major producers of tea in the world, tea leaves harvesting machine will have an important role in improving the tea production.

2. LITERATURE REVIEW

   Literature survey and review is carried to collect data and understand about Tea leaf harvesting machine, present and future trends in product design and application of it to design, and designing for aesthetics.

2.1 “Mechanical harvesting of tea in Central and southern African region”: Martin

   Argentina started mechanizing of tea harvesting in early 1970’s. Shortage of labor lead to mechanizing of tea harvesting among the member countries of Tea Research Foundation of Central Africa, South Africa was the first among them to start using machine. Since in most of the region the tea harvesting machine is in its infancy simpler types of machines were used.

   Most of the estates tried shear plucking as a part of cost reduction. Majority has banned this since the productivity was not as expected and the bushes were damaged. In most of the estates hand held machines were used since they are suited for hilly terrain. These machines were single or double man operated. 3 or 4 men operated 2 or 4 stroke engine powered machines with wheels were introduces later. These machines have sizes from 1.2m to 2.4m. Generally the machines with four wheels have better control over maintaining the height of the bush than two wheeled machines, since they have a tendency to tilt.

   The output with the machines is 350 kg green leaf for single man operated machine and 900-1200 kg for two man operated [1].

2.2 “Tea leaf harvesting – An Ancient Art Form”: Steve Greens

   The right amount of rain and sun of the sub tropical climate as well as the mountainous terrain along with the acidic sand provides the distinct flavour of the tea. Picking of tea has to be done by hand to preserve the integrity of leaves before harvesting. Hand plucking involves plucking of leaves without damaging the stem. Using of machine increases the amount of bruising and number of stems included in the harvest and will result in poor quality of tea.

   Tea bushes will reach up to thirty feet. This makes the harvesting difficult. In tea farming the height of the bushes are maintained at a comfortable height for easy plucking of the leaves and buds. Pruning the plants in comfortable heights regularly train the plants to produce leaves tightly around the area easily accessible by hand. The process of tea harvesting requires quick eye and fast hand. Up to one pound of tea is produced from a single tea plant [2].

2.2.1 “Commercial Crop Technology: Vol.08 Horticulture Science”: Alice Kurian

   Countries like Japan and Russia have started mechanical harvesting in order to reduce the labour cost during plucking. Now India is also trying this. South India has a distinct cropping pattern with alternate high cropping and low cropping period. One of the serous problems in tea harvesting is the unavailability adequate number of labourers. This problem can be solved to an extent with the help of integrating machines for harvesting. Mechanized harvesting helps in reducing the man hour. These machines require additional worker for leaf collection and keeping the bags properly. The output for mechanical harvesting is 1000kg/8hr compared to 25-40kg plucked by operator. Machine harvesting cannot be done in closely spaced section [3].

2.3 “The Biography of Tea”: Carrie Gleason

   The tea leaves of new tea plant are ready for harvesting in five years. The growth of the plant is not uniform throughout the year. The environment where the plant is growing has a great influence in the plant for the production of new buds and leaves and also the number of harvesting.

   In some places tea have a dormant winter period and a growing season. Harvesting is mostly done by women and each day they are set with a quota or a set amount of leaves to be picked. 30kg per day is the harvesting of an experienced picker. Hand picking of tea leaves are recommended since only the bud and the top two leaves are removed [4].

2.4 “Tea harvesting in different part of the world”: Francois-Xavier Delmas

   In south Sri Lanka, individual farmers cultivate tea in their own land and will sell the tea after harvesting since they don’t have the infrastructure to process them. They will sell these leaves to the local factories. An inclined plane is ideal for tea growth since it is easy for the rain water to run away. In flat regions drainage system should be maintained for growing healthy bushes. Tea plucking is done only by women and other jobs by men in most of the region [5].

2.5 “Coffee, tea and cocoa: an economic and political analysis”: Vernon Dale Wikizer

   Selection can be made carefully if the plucking is done with hand. In Japan shears were employed in harvesting and the tea bushes were maintained as ornamental plant. The introduction of shear has increased the output per person but have less control over quality. Rising labour cost has resulted in mechanizing tea harvesting. The fineness and coarseness of the plucking depend upon the number of leaves taken and the time given between plucking rounds [6].

2.6 “4 Factors in Ergonomic Hand Tool Design”: Sarah

   Handle design have great influence efficiency as well as safety in all kind of daily activities. The handle diameter should be thick enough to separate the finger tips from palm. For power grip the length of the handle should be 10-15cm and the diameter should be 3-4cm [9].
3. PROBLEM DEFINITION

3.1 Product Study

Tea leaf harvesting is done manually and by machine. A tea leaf harvesting machine is a device used for easy harvesting of tea leaves with minimum number of laborers. Manual harvesting can again be classified as hand plucking and plucking with the help of scissors. Machines are of two types - petrol/gas operated and battery operated.

The main parts of a petrol/gas operated tea leaf harvesting machine are cutter, blower and two stroke engine and collection bag. From the energy produced from the engine the cutting process is done and the blower blows these leaves into the bag. Battery operated harvesting machine consists of cutter, a flap for moving the leaves into the bag, collecting bag, dc motor and a battery.

Fig. 2 Petrol/Gas operated machine

The 2 stroke engine is being carried on the back by the operator. From the engine the power is transferred to the blower and the cutting blade. The cam mechanism to which the blades are connected rotates which results in the reciprocating movement of the blades which are placed one above the other. This reciprocating movement results in the cutting of the tea leaves. The air coming out from the blaster outlet moves the detached tea leaves to the bag connected. Once the bag is filled, it is replaced with a new bag.

The petrol operated machine has a harvesting capacity 900 kg/day. The weight of the machine is around 17 kg.

In a battery operated machine, the energy source is a 12v 7.5 Ah battery. From the power obtained from the battery the DC motor connected to that rotates. Rotating motion from the horizontally kept motor to vertical direction is achieved with the help of bevel gears. The fast rotating blades are responsible for the cutting of the tea leaves. The metal plate that is connected to the axis of the blade is responsible for the transferring of cut leaves into the bag attached. When the bag is filled, it is replaced with the new bag.

Fig. 3 Battery operated harvesting machine

The battery operated machines have a harvesting capacity of 30kg/hr. The machine and the battery weighs around 3kg each.

3.2 Market Study:

A market study was carried out to understand the different types of machines available in the Indian market for harvesting tea leaves. The market study was very helpful in understanding about the different manufacturers’ tea leaf harvesting machine in India as well as abroad. A detailed study was done on machines available in India, especially about the features like harvesting capacity, weight of the machine, easiness of handling, clear vision of the process, cleaning, servicing etc.

Fig. 4 Different types of machines for harvesting

i. Market Study key findings

- Price of the machine ranges from Rs 20,000 to Rs 90,000
- Petrol/gas operated, battery operated and scissors type
- Single man operated to four men operated
- The machine mainly consists of metals parts, plastic and rubber
- The machines are supplied as per order received
- No much importance is given for ergonomics and aesthetics
### ii. User Study:

Design process was carried out through different steps which include literature survey, product study, market study and user survey. A vast survey has been conducted within the user to know more about the problem they are facing and to arrive at a new design. The customers or the users are given prime importance. The user survey helps to understand the ways through which the people are using the product and the difficulties which they are facing.

#### 3.3 Customer’s voice.

The key finding from the gemba study conducted to understanding more about the current situation and the real time problems are listed below:

- Increasing price, fumes and smell, body pain due to overweight are the common complaints about petrol operated machine. This machine consumes 600ml of petrol per hour. Damage to tea leaves is the complaint about battery operated machine. Body pain while using scissor type harvesting are the major observations.

#### 3.4 Ergonomic Study

The anthropometric data that were considered for designing the machine are the hand inside diameter, width of the palm and the thickness of the finger. These entities are considered while designing the handle for the machine. The dimensions are as per Indian Anthropometry. Although the inside diameter of the palm is given as 40mm, for power tool it can be between 30-40mm.

#### 3.5 Quality Functional Deployment (QFD)

The QFD matrix helps in identifying the important factors that affect the design of the machine. It also helps in prioritizing the factors based on their importance and their impact on the overall design.
3.6 Product Design Specification (PDS)

<table>
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<tr>
<th>Table 26 PDS</th>
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<tbody>
<tr>
<td><strong>Product name</strong></td>
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<tr>
<td><strong>Target user</strong></td>
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<td><strong>Usage</strong></td>
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<td><strong>Type</strong></td>
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<td><strong>Weight</strong></td>
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<td><strong>Price</strong></td>
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<td><strong>Working duration</strong></td>
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<td><strong>Energy source</strong></td>
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<td><strong>Lifespan</strong></td>
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4. PROBLEM STATEMENT

Tea is a major beverage in India. Tea is prepared by steeping processed leaves or buds in water. The study about understand the tea leaves harvesting methods and to developing a new tea leaves harvesting machine. The shortage of laborers and the increase in wages paved way for mechanizing the process of tea leaf harvesting. Tea leaf harvesting machine helps in increasing the output rate of tea harvesting with reduced man power. Since India is one of the major producers of tea in the world, tea leaves harvesting machine will have an important role in improving the tea production.

4.1 Methods and Methodology

- Literature review on Tea leaves harvesting machine was carried out by referring books, magazines, journals and other related documents.
- Data collection was done by user study and market study through interviews, images, videos etc.
- QFD was generated based on the customer requirements and corresponding technical requirements, and PDS was generated by prioritizing the features in the QFD.
- Concepts was generated by sketching, adopting various concept generation techniques like brainstorming, mind mapping etc.
- Five concepts were generated and were converted into digital model with the detailed features using Alias studio tools, CATIA, Adobe Photoshop.
- Final concept was selected by weighted ranking method.
- Mock-up model was made with detailed features and feedback are collected

5. CONCEPT GENERATIONS

5.1 Mind mapping

Mind mapping is the diagrammatic representation of idea generation. Mind mapping gives a clear idea of the required data’s and the relation with the product. In mind mapping the central part is the product and the accessories and the relation are placed as branches all around the product. This structure will helps to visualize and understand the structure, problem solving and for making a decision.

5.2 Concept 1

![Fig. 9 Concept 1](image)

In concept 1 rotating blade is used for cutting leaves. This is a single hand operated machine. The non metallic twisted sheet acts as the blade. This blade while rotating pushes the leaves against the permanent blade for cutting and then pushes the leaves into the net like bag attached to the back side of the machine. This is replaced when it is filled.

The advantages of this machine are light weight, easy to operate, easy cleaning and servicing, selective harvesting and less damage to tea leaves. The disadvantage of this machine is the improper vision of the operation.

5.3 Concept 2

![Fig. 10 Concept 2](image)

Concept 2 is the modification of the existing battery operated machine of ‘K-Tech’. The harvesting of tea leaves is done with the help of rotating blade. In this the flap is integrated with the blade. This will prevent the leaves from getting damaged. The collection bag is attached in the back side. The cut leaves are pushed into the bag with the help of flap. The ‘V’ shape will help in guiding the leaves for cutting. Two switches are provided in the handle for safety.

The advantages of this machine are light weight, easy holding and operating, less damage to tea leaves and selective harvesting. The disadvantages of this machine are poor vision of the operation, difficulty in cleaning and servicing.
5.4 Concept 3

Fig. 11 Concept 3

Concept 3 is the modification of the existing harvesting method, with the help of scissors. This consists of a permanent blade and an oscillating blade. Cutting of the tea leaves is done with the help of oscillating mechanism. The cut leaves are moved into collection box with the help of baffle. When the box is filled, it is transferred to the bag.

The advantages of the machine are simple, easy to hold and operate, clear vision of the process, minimum damage to the leaves, double switch for safety, selective harvesting, easy cleaning and servicing.

5.2 Concept 4

Fig. 12 Concept 4

Concept 4 is similar to concept 1. The tea leaf is cutting with the help of rotating blade. Three blades that are kept equal distant apart are responsible for tea leaf cutting. The collection bag is attached to the back side. After cutting the leaves they are being pushed into the bag. When the bag is filled it is replaced empty bag. Two switches are provided along with handle.

The advantages of this machine are it is light weight, easy holding and operating, less damage to tea leaves, selective plucking. The disadvantage with this machine is poor vision of the operation, difficulty in cleaning and servicing.

5.2 Concept 5

Concept 5 is a modification of concept 3. In this concept there are 2 permanent blades and one oscillating blade which will cut the tea leaves in both to and fro motion. Collection bag is attached with both permanent blades. Once the bags are filled, the operator can transfer it into the sack or the bags provided. The handle design is inspired from grass cutting machine.

Fig. 13 Concept 5

The advantages of this machine are that it is light weight, easy for holding as well as for operating, selective harvesting, less damage to tea leaves, has double switches for safety, clear vision of the operation, easy cleaning and maintenance. The disadvantage with this concept is that the chances for the tea leaf falling off from the collection bag is more since the cutting action takes place in both the directions.

5.2 Concept selection

Table 27 Weighted ranking method

The final concept was selected with the help of selection matrix. In this method the concepts are compared with each other with some selection criteria. Each criteria is given wait age according to the importance of each problem. From the final score obtained concept 3 was selected as the final concept.

6. DETAIL DESIGN AND PROTOTYPING

6.1 Final Concept

Fig. 14 Final concept
The final concept was selected and the selected machine resembles the existing scissor for tea leaf harvesting. But here the operator does not have to take strain of cutting, instead he has to press the push button switch provided on the handle. The oscillating blade oscillates, cuts the leaves and with the help of baffle it is transferred to the collection basket. When the basket is filled, it is transferred to the collection bag.

It is a common phenomenon that the people especially the elder people find it very difficult to adjust themselves to a new scenario. But for this machine although it is new and mechanized, the overall look of the machine remains the same as that of the existing scissor type. This helps everyone including the elder people to get adjusted by the mechanized tea harvesting very soon. This improves the production in minimum time. With this machine the operator can have a proper vision of the process. This helps him to do selective harvesting there by improve the quality of tea. The cleaning as well as servicing of the machine is also very easy.

6.2 Exploded View

The exploded view gives a clear view of the various components that constitute the machine. This also gives an idea of placement of the various parts. This view gives a clear idea of assembling as well as dismantling of the machine.

6.3 Mechanism

The picture gives a clear idea of the mechanism of the machine. Here with the energy from the battery the DC motor rotates. This rotates the attached disc. A link is attached to the disc. The other end of the link is attached to the stem in the oscillating blade. When the disc rotates; the link slides up and down through the stem. Since the oscillating blade is pivoted in between the sliding movement of the link is transformed as oscillating movement. This results in the cutting of leaves as well as moving the cut leaves into the collection basket attached to the permanent blade.

6.4 Mock Up Model Making

A mock-up model of 1:1 scale was made. A mock-up model is a full or scaled model of the concept. Mock up model help to know the dimension, testing etc.

i. Material Used for Making the Mock Up Model

- 3mm thick sun board was used for fabricating the collection basket
- PU foam is used for making the motor casing
- The handle made in wood
- The blade were made up of mild steel
- The support is also with mild steel
- The top cover was made with 2mm clear acrylic sheet
- The baffle was made with 3mm sun board
- The handle support was made up of galvanized iron pipe
- The required holes are made with drilling machine
- The blades are permanently fixed by welding
- The sticking of the basket is done with cyanoacrlite bond
- Spray painting was done for finishing
7. SUMMARY

From the present study, the proposed concept appears to show a potential saving of 15% in weight, and should therefore likely find acceptance in the field.

8. REFERENCES