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THE STUDY ON DESIGN OF VERTICAL FERMENTATION UNIT FOR THE TEA MANUFACTURING INDUSTRY

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ABSTRACT
India is the one of the top producers and exporters of tea in the world has been facing some challenges in recent time. The problems and challenges are not tackled timely and effectively. The tea board of India has recently approved to developing mini and micro tea factories to improve the plucking standards and develop the innovative ideas. However, there is a lack of innovation in tea plant industry practices which is considered as one of the most challenging works. The project paper presents the design of vertical fermentation units particularly in the fermentation process in the tea industry. Also, the utilization of waste heat from the tea fermentation process by implementing the heat recovery units. The utilization process leads to reduce the need of energy and the area consumption in a tea industry. The paper of the project will face the challenge by recovering waste heat during fermentation process in tea industry thus by reducing the need of excess energy and there is the development in updating new channel of tea industry first and foremost to establish various tea entrepreneurs.
Keywords: Innovation in tea industry, updating new channel, vertical fermentation.

1. INTRODUCTION
Tea is the second most consumed beverage in the world. All teas (black, green, oolong, white and powder) come from the same plant. The scientific name of this plant is Camellia sinensis. Camellia sinensis is a subtropical, evergreen plant native to Asia, but is now cultivated worldwide. Tea plants grow best in loose, deep soils, high altitudes and subtropical climates. Tea in India is grown primarily in Assam, West Bengal, Tamil Nadu and Kerala. Apart from this, it is also grown in small quantities in Karnataka, HP, Tripura, Uttaranchal, Arunachal Pradesh, Manipur, Sikkim and Meghalaya.
The three most distinct known varieties of tea in India area are Assam tea (grown in Assam and other parts of NE India), Darjeeling tea (grown in Darjeeling and other parts of West Bengal) and Nilgiris tea (grown in the Nilgiris hills of Tamil Nadu). The industry needs to be competitive in production, marketing, logistics and product forms. India, despite being a large producer of tea, lacks properly organized production systems in which small tea producers find a respectable place. The innate flavor of the dried tea leaves is determined by the type of cultivar of the tea bush, the quality of the plucked tea leaves and the manner and quality of the production process they undergo.

1.1 TEA CATEGORIES
The categories of tea are distinguished by the processing they undergo. In its most general form, tea processing involves different manners which involves degrees of oxidation of the leaves, stopping the oxidation and forming the tea and drying it. Based on the degree or period of oxidation or fermentation the leaves have undergone, tea is traditionally classified as Green tea, Yellow tea, White tea, Oolong tea and Black tea.

1.1.1 GREEN TEA- Green tea has undergone the least amount of oxidation. The oxidation process is halted by the quick application of heat after tea picking, either with steam, or by dry roasting and cooking in hot pans. Tea leaves may be left to dry as separate leaves, or they may be rolled into small pellets to make gunpowder tea. The tea is processed within one to two days of harvesting, and if done correctly retains most of the chemical composition of the fresh leaves from which it was produced. Green tea leaves undergo fixation by either roasting (panning) or steaming.

1.1.2 YELLOW TEA- This tea is processed in a similar manner to green tea, but instead of immediate drying after fixation, it is stacked, covered, and gently heated in a humid environment. This initiates oxidation in the chlorophyll of the leaves through non- enzymatic and non-microbial means, which results in a yellowish or greenish-yellow color. Yellow tea goes through a longer oxidation process than green teas and a slower drying period and its caffeine content of about 32 mg per 8-ounce cup.

1.1.3 WHITE TEA- White tea is not oxidized, just like green tea. It has a lighter flavor than black and is known for its floral and fruity aromas. Some choices for white tea include. The amount of caffeine in white tea can vary from about 15 to 20 mg of caffeine per 8-ounce cup.

1.1.4 OOLONG TEA- Oolong tea goes under partial oxidation. Many people compare the flavor of oolongs to flowers or fruit. A few great blends of this tea include Toasted Nut Brulee caramel nut tea, Cream peach oolong tea, and Currant Conversation best black currant tea. This tea's oxidation is stopped somewhere between the standards for green tea and black tea.

1.1.5 BLACK TEA- Black tea goes through a process called oxidation where water evaporates out of the leaf and the leaf absorbs more oxygen from the air. Black tea specifically goes through the full oxidation process, resulting in dark brown and black leaves. The tea leaves are allowed to completely oxidize. Black tea is first withered to induce protein breakdown and reduce water content (68–77% of original). The leaves then undergo a process known in the industry as disruption or leaf maceration, which through bruising or cutting disrupts leaf cell structures, releasing the leaf juices and enzymes that activate oxidation.

2. TEA MACHINES

2.1 TEA GREEN LEAF WITHERING PROCESSING MACHINERY

1. Withering trough with fan
2. Green leaf feeding conveyor
3. Even feeding system with control

2.2 TEA ROLLING ROOM CUTTING PROCESS MACHINERY

1. Green leaf shredding machine
2. Rotor vane machine
3. CTC cutting machine
4. Googi rotary drum
5. Continues fermenting machine
6. Ball breaker machine
7. Dryer feeding conveyor
8. CTC shell dismantle monorail

2.3 TEA POWDER GRINDING PROCESSING MACHINERY

1. Pulverizer
2. Screw conveyor
3. Screw feeding elevator
4. RC dust storage bin

2.4 TEA DRYING PROCESSING MACHINERY

1. Dryer with hot air impeller
2. Heater
3. Id fan
4. Cymene
5. Dryer discharge elevator
6. Bulk storage bin lone
7. Heater
8. Id fan
9. Cymene

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10. Dryer discharge elevator
11. Bulk storage bin

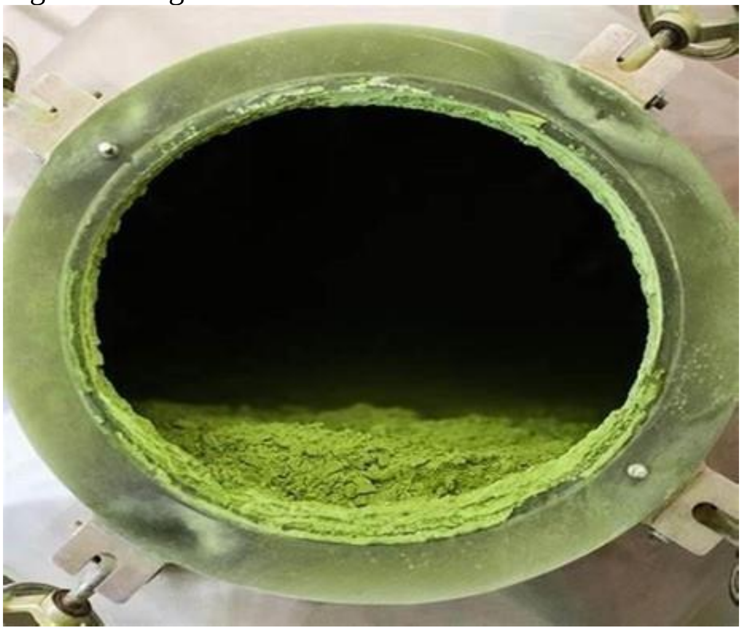
2.5 TEA GRADING & SIFTING ROOM MACHINERY

1. Jumbo fiber extractor machine
2. Trinix sorting machine
3. Storage bin 5 in 1
4. Bin feeding elevator
5. Bin discharge conveyor
6. Feeding elevator
7. Final cleaning fiber extractor
8. Winnower
9. Packing bin

2.6 FERMENTATION MACHINE

EXISTING FERMENTATION DRUM- The fermenting drum is a simple cylindrical drum with conical feeding and discharge ends. The standard drum is 4.8 – 6.1 m (16- 20 feet) long and has a diameter of 1.5 m (5 feet) at the cylindrical portion. The total length of the conical segment is four feet. The capacity of the drum will be 5.2 kg of rolled dhool for every square meter area of the drum. The mechanical aspects involve spreading out of leaves in a layer 5 -8 cm thickness and maceration by rolling. The fermentation time is generally 45 minutes to 3 hours depending on the quality of leaf. Fermentation vessel can make the process continuous.

Fig.1 Existing fermentation drum



CONTINUOUS FERMENTING MACHINE - It helps to eliminate microbial contamination in tea. Microorganisms occur as contaminants during tea processing due to the presence of a layer of fermented juice on the processing machines and other equipment.

Fig.2 CFM

The CFMs consist of a tray made up of conveyor racks with three to four tier systems like "quality" drier arrangements. The fermented dhool travel in a thin layer on the conveyor rack. Above or below the tray, UV lamps are fitted which are used to kill the external bacteria and triggers the activity of polyphenol oxidase, thereby hastening the biochemical reaction. Bright infusions are obtained in the continuous fermenting machine. This machine is generally used for NRC tea manufacture. In RC tea manufacture googhie sifter is used before CFM for granulation of tea.

2.7 DRYING MACHINE

ECP DRIER- The Endless Chain Pressure type driers consist of two or three individual tray circuits. When the leaf is fed into the feeding circuit, the spreader spreads the leaf uniformly on the tray. As soon as the leaf completes the run-on top circuit, the tray carrying leaf is automatically tilted at the end of the circuit and the leaf falls on the mid circuit where direction of tray movement is opposite to that of top circuit.

Fig.3 ECP

Thus, the leaf is subjected to gradual high temperature from top to bottom circuit and drying is

completed when the leaf reaches the bottom circuit. The total drying time is 20-22 minutes. The output of the drier is 200-250 kg made tea with the feeding moisture level of 55%. The inlet and exhaust temperatures may be maintained at 100°C and 55°C, respectively.
FLUID BED DRIER - It Consists of drying chamber, plenum chamber, air flow damper and dust collectors. The drying chamber is separated by a perforated grid plate through which high pressure hot air from the plenum chamber gets into the drying chamber for fluidization. The plenum chamber is divided into four zones which have individual air control valves. These valves control the quantity of air to the individual zone and the direction of hot air entering the control dampers.
At the top of the drying chamber two centrifugal exhaust fans are fitted with cyclone, one for refiring and the other for dust extraction. When the fermented dhool is fed into the drying chamber in the first zone it gets fluidized. With the help of pressurized hot air, water is removed by evaporation. The inlet and exhaust temperatures for FBD may be maintained at 250°F to 260°F and 150- 160°F for achieving better quality.
COMBINATION DRIER- Tempest drier is a combination of conventional and fluid bed drier. In the tempest drier on top of the drying chamber i.e., above the fluidization zone there is a tray moving inside which carries the fermented leaf from the drum where surface moisture is removed by exhaust temperature. Since a certain percentage of moisture is removed from the leaf before entering the fluidization zone, the output of the drier is higher than conventional FBD.
VIBRO FLUID BED DRIER - It works on the principle of ‘vibrating fluidized bed’. It works on pneumatic and mechanical power. The fermented teas are fed through a feed system into the drying chamber. Hot air from the heater is passed from underneath to the drying chamber through the perforated tray carrying wet teas. The tea leaf is effectively fluidized by a combination of air pressure and mechanical vibration.

3 DESIGN THINKING IMPLEMENTATION
3.1 EMPATHY
1. Need of external power supply in drying during fermentation process.
2. Requirement of large area consumption.
3. Excess heat losses during fermentation process.
4. The size of the equipment's is heavy and large.
5. Repair of the huge machines is more expensive.
6. Service and maintenance of the machines is high in cost even in working and ideal conditions.

Fig4. Conveyors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3.2 DEFINE

PROBLEM STATEMENT

Excess heat loss and external power source is needed for drying in fermentation process. During the fermentation process the excess of waste heat is dissipated to the surrounding area of the industry, thus waste is neither conserved nor utilized in the useful form. This project paper projects of recovering waste heat by the way of observing which is wasted to the surrounding environment.

Fig.5 Fermenting unit

3.3 IDEATE

Stepping the fermentation structure by emplacing some equipment's such as conveyors, fermentation plate, heat pipe, heat pumps and vibrators. The waste heat is utilized in the process during the fermentation by changing the structure of the fermentation process. The obtained result is analyzed through the CFD technique.

4. METHOD OF PROPOSAL

4.1 PROJECT IMPLEMENTATION

The upcoming process is to be updated as by following requirements to be done.

1. The complete structure of the flow channel in the tea industry must be changed as per our design prototype set up.
2. The implementation of the various equipment's such as conveyors, heat pipe, vibrator, fermentation plate, heat pump. These devices must be implemented as per the design prototype which is designed and analyzed by CFD technique in future.
3. The project working nature must be undergone in isolated environment so that to get accurate results.
4. The working model of the prototype setting is more complicated and hence implementation can be done by setting the mini prototype, so that to get some approximate results.
5. Ultimately, the projection of the project model is soon to be updated, and the result is observed, compared and analyzed.

4.2 DESIGN IMPLEMENTATION

The model prototype is totally changing the structure of the tea flow channel in an industry, and it mainly targeted to reduce the requirement of large area infrastructure and enhance for building the factory even for individual purpose finally to promote the development of entrepreneurs. The testing is done by Working of prototype model and analysis of model by CFD ANSYS technique.

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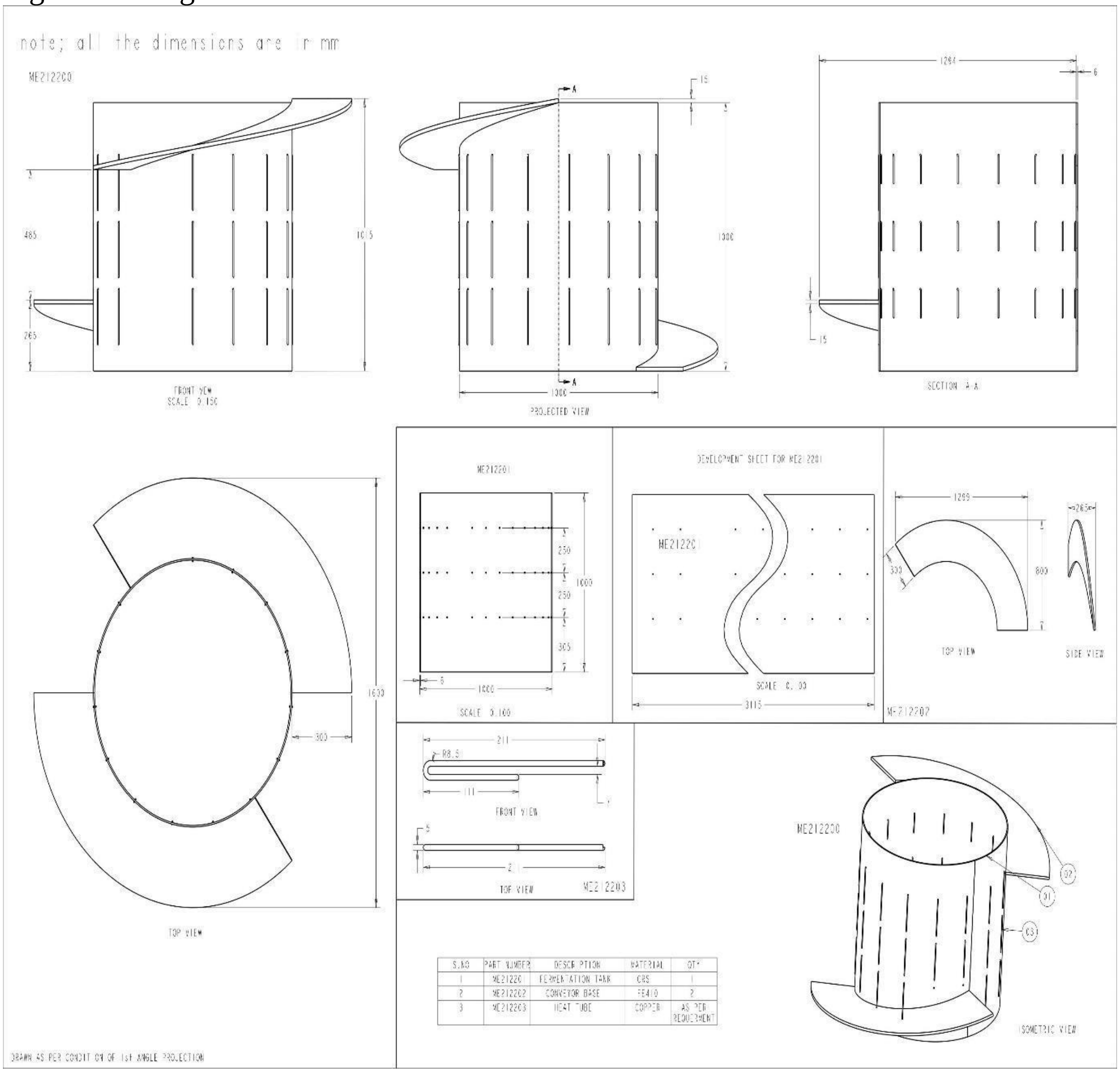
Fig.6 2D Design



The following parameters and the factors which affect the design are required in the design implementation respectively.

Table.1 Design Parameters

Software	Creo, Ansys, AutoCAD
Material	CRD CS SHEET MET,
Dimensions	Fermentation-tank (1m x 1m x 1m) Fermenting plate (300mm L x 250 B x 6mm W) Sheet metal (1000mmL x 3115mm B x 6mm W) Heat pipe 45 nos Vibrator 4nos Conveyors, Supports and fittings, Heat pump (asper the requirement)
Machines	Grinding machine Turning-machine Arc-welding Gas-welding

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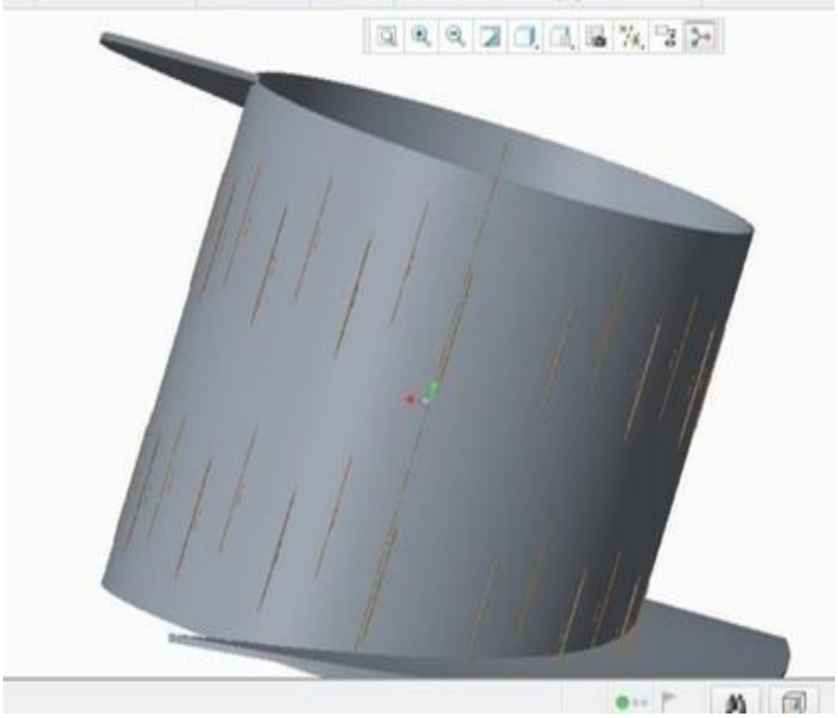
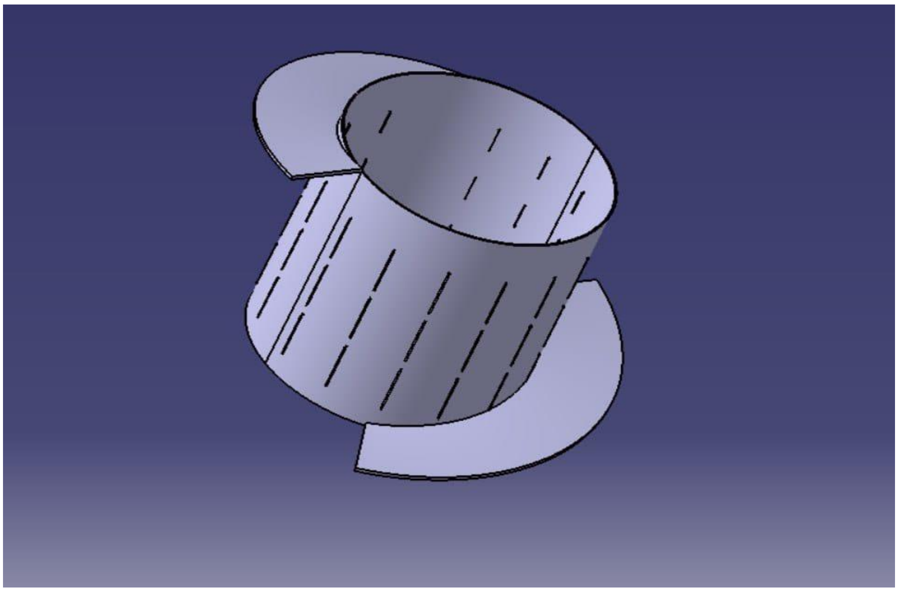
Fig.7 3D Model design





4.3 MACHINES FOR IMPLEMENTATION

The following methodology can be obtained by using the various equipment's such as Conveyors, Heat pipe, Fermentation plate, Vibrator, Heat pump.

Conveyors- Conveying tea is not without its challenges from dusting and degradation to maintaining batch integrity. The paper examines the mechanical conveying range, and each bulk material conveyor will be suitable for conveying tea.

Heat Pipe- A heat pipe consists of a working fluid, a wick structure, and a vacuum-tight containment unit (envelope). The heat input vaporizes the working fluid in liquid form at the wick surface in the evaporator section.

Phase-change processes and the two-phase flow circulation in the heat pipe will continue as long as there is a large enough temperature difference between the evaporator and condenser sections. The fluid stops moving if the overall temperature is uniform but starts back up again as soon as a temperature difference exists. No power source (other than heat) is needed. In some cases, when the heated section is below the cooled section, gravity is used to return the liquid to the evaporator. However, a wick is required when the evaporator is above the condenser on earth. A wick is also used for liquid return if there is no gravity, such as in NASA's microgravity applications.

Fermenting Plate- The leaves which are after rolling process the residues are kept in fermented plate which can be fermented, or drum fermented where the chemical composition of enzymatic oxidization takes place.

Mechanical Vibrator- The fermented tea is spread over the perforated bed through a mechanical feeder and spreader. The tea is fluidized by hot air pushed into the drying chamber through an aerodynamically designed plenum chamber and the mechanical vibrator which moves the teas forward. The tea is dried uniformly, and the moist air is discharged in the atmosphere. The exhaust air from the last zone is recirculated into the air heater to improve fuel efficiency.

Heat Pump- A heat pump is a device used to warm the interior of a building or heat domestic hot water by transferring thermal energy from a cooler space to a warmer space using the refrigeration cycle, being the opposite direction in which heat transfer would take place without the application of external power. In the process of fermentation, the heat pump is the main heating source and must be maintained at needed temperature.

4.4 ENERGY MANAGEMENT APPROCH

Tea manufacturing involves the following energy intensive operations: withering, maceration, fermentation, drying and grading/packing. Industry uses natural gas as a source of thermal energy. Around 2550 kg of green leaf is withered in a single shift of withering. The flame strength in the gas burner is 422.9kW. The maceration equipment is sub-divided into- Rotor-vane and CTC.

The withered leaves weighing 600 kg undergo the maceration process. Time taken for the completion of this process is 1 h. Drying is one of the energy intensive operations. The conventional pressure chamber type dryer is used by industry. The natural fermentation process does not require energy unless humidifiers are used. The use of humidifiers depends on the humidity of surrounding air, hence making it difficult to estimate the power consumption.

The weight of the leaves after fermentation comes down to 170 kg and the time required for drying is 1 h. Flame strength in drying is 845.8 kW. The dried tea is sorted into different grades by passing it over mechanically oscillated sieves for grading. Every tea estate has its own method of fiber extraction. The dried leaves now weigh 120 kg, and the time required for fiber extraction is again 1 h. Energy management is an approach to manage energy usage and reduce energy costs.

4.5 ENERGY CONSUMED

The energy consumed (thermal and electrical) in kWh is calculated for 100 kg weight. It is evident that drying is much energy intensive in comparison to the other processes, for the drying of 100 kg of fermented tea consumes 6.23 kWh of electrical and 497.53 kWh of thermal energy. Some energy efficient technologies may be adopted by the tea industry which in turn will reduce a considerable amount of production cost.

1. The power consumption in withering can be reduced to 0.08 units/kg of made tea by using an aero foil bladed adjustable pitch fan with a dual speed and dual rating energy and by using fiber reinforced plastic fans.
2. By replacing the manually operated rollers with automatic rollers, the efficiency of the motor may be increased to 75%.
3. The use of solar thermal energy may reduce the withering time thus saving electrical energy.
4. Use of proper starter, CFL bulbs and electric control system.
5. Use of variable speed driven motor and appropriate capacitor bank.
6. A considerable amount of heat energy could be recovered from the flue gas and dryer exhaust.

7. Use of solar thermal energy and the use of efficient heat exchangers.
8. Running the burner at optimum air-fuel ratio as per load demand.
9. Recirculation of exhaust air from the dryer.
10. Use of fuel-efficient air heaters and proper insulation
11. All these methods may help the industry management to find out their drawbacks as far as the utilization of energy is concerned and guide them positively towards the improvement of productivity in terms of cost of energy and production.

5. CONCLUSION

Thermal energy contributes about 88-92% of the total energy consumption in tea factories. More than 80% of the energy required is thermal energy to remove moisture during withering and drying, whereas electrical energy is required in almost all stages. The updated results are compared and analyzed in both resulting processes. Thus, the project finalizes the amount of recovering waste heat during fermentation process thus to reduce the need of external energy source. From the result verification of CFD technique, the project is implemented by concluding that to enhance more small business entrepreneurs to achieve the individually and also globally in the competitive society. Ultimately, innovation is achieved in implementing the project in the tea industry.

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