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CONSERVATION OF ELECTRICAL ENERGY IN TROUGH WITHERING

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Electrical energy is required for the unit operations of Withering, Rolling, Roll Breaking and Drying in black tea processing. Electricity consumption in sorting and packing operation is rather small. Bulk of electricity consumption takes place in the unit operation of withering. Results from this study clearly show that the airflow rate required for withering process could be regulated according to the moisture removal rate of the green leaves. It was observed that more than 50% of the moisture removal takes place during the first four hours of the withering process. Up to 40% of electricity consumed in the withering process could be saved by proper control of airflow in the withering process by installing variable speed controllers, without affecting the quality of tea produced.

INTRODUCTION

Tea Industry in Sri Lanka is the largest industrial consumer of electricity, and one of the major consumers of oil. At the same time, it is the largest fuel wood consumer utilizing approximately 33% of the industrial consumption (Haskoning, 1989). Unit operations involved in black tea processing could be summarized as Withering, Rolling, Roll Breaking, Drying, Grading and Packing. Main objectives of withering are, to reduce moisture content of the leaf to concentrate the juices and bring the physical condition to a "rubbery" state in which it will stand twisting without breaking up into flakes.

Electrical energy is required for the unit operations of Withering, Rolling, Roll Breaking and Drying. Electricity consumption in sorting and packing operations is rather small. The actual energy consumption in typical high/mid and low-country factories observed by analysis of historical data and by actual measurements during energy audits is given in Table 1 (De Silva, 1994).

Table 1: Electrical energy consumption in unit operations of tea processing

	Mid/High Country		Low-Country	
	kWh/kg of made tea	%	KWh/kg of Made tea	%
Withering	0.46	48.9	0.46	61.3
Rolling	0.20	21.3	0.10	13.3
Drying	0.07	7.4	0.07	9.3
Sorting & Packing	0.09	9.6	0.07	9.3
Ancillaries (incl. Domestic use)	0.12	12.8	0.05	6.7
Total	0.94	100	0.75	100

From Table 1, it will be seen that the bulk of electricity consumption takes place in the unit operation of **withering.** A large volume of air is used by means of electric fans during the withering process for removal of moisture from tea leaves, under controlled conditions. Specific electrical energy consumption applicable, under ideal situation, to troughs of any size is only 0.16 kWh/kg made tea, for withers lasting 12 hours and 0.25 kWh/kg made tea for withers lasting 18 hours, as against observed specific consumption of 0.46 kWh/kg made tea (De Silva 1994).

The reasons for such high electricity consumption in withering process are;

1. Installation of over-size motors and fans.
2. Improper loading and loosening of leaf.
3. Fan starvation due to improper adjustments of air dampers and inappropriate ducting in front of the fan.
4. Delivering air with high humidity i.e air with hygrometric differences of less than 4°F, for withering.
5. Leaving the fan on (with gable end door open) even after wither has been achieved. (Ziyad Mohamed, 1998).

Withering Process

If fresh tea leaves are rolled in conventional tea rollers without withering, it will break up into small flakes and the resultant tea will be unacceptable to the tea trade. The conventional tea roller is designed to twist or wring the tea leaves. The leaf must be conditioned to stand up to such treatment. Main objectives of withering are therefore, to reduce moisture content of the leaf to concentrate the juices and bring the physical condition to a "rubbery" state in which it will stand twisting without breaking up into flakes. One of the first essentials of withering is therefore, to get a correct physical condition which will not only allow leaf to be rolled without breaking up, too quickly, but which will prevent the draining out of juices from the leaf.

In addition to the physical changes, chemical changes also occur within the leaf cells, during the withering process. To achieve these physical and chemical changes, fresh tea leaves are spread on withering troughs and air is blown through the leaves using large fans. In withering, electricity is consumed by the fan motor which operates, continuously for about 12 to 18 hrs.

Following analysis shows that Research and Development relating to withering operation could effect considerable energy savings.

Moisture removal

The amount of moisture to be removed from the green tea leaves may vary according to the leaf structure and especially on the prevailing weather condition of the day. More than the rainfall ambient conditions (temperature and humidity) have a greater influence on the removal of moisture from leaves.

During the initial phase of the withering process, moisture on the surface of the leaf gets evaporated. When the surface moisture is absent, the diffusion process within the leaf controls the evaporation rate. The moisture removal rate becomes slower and slower, when diffusion is taking place from interior cells. At the initial stages, removal of moisture from the surface and cells closer to the surface, could be accelerated by proper control of wet and dry bulb temperatures. The moisture removal rates are considerably low during the latter part of the withering process, and it varies with the characteristics of leaf structure (Samaraweera, 1986).

It was observed that more than 50% of the moisture removal takes place during the first four hours of the withering process. Though, there are other parameters which govern the moisture removal such as free area available for evaporation, surface film coefficient etc. initial investigations reveal that the amount of air supplied for withering is more than what is required, and it could be regulated according to the moisture removal rate.

In these trials, troughs of size 70' x 6' (21.34m x 1.83m) with a loading rate of 26.9 kg/sq.m (2.5 kg/sq ft), giving a total load of 1050 kg green leaves per each trough were used. By measuring the weight loss of three samples placed on the withering trough, the rate of moisture removal during the withering process was monitored. The results are shown in Figure 1. It was observed that, more than 50% of the moisture removal takes place during the first four hours of the withering process, which clearly illustrates the phenomena described above.

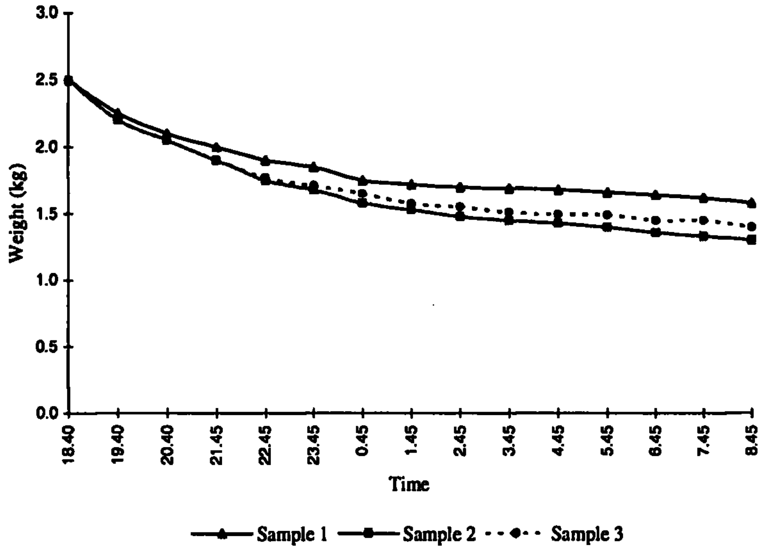

Figure 1: *Weight loss of green tea leaves during withering*

Generally, a constant rate of airflow is maintained throughout the withering process. Figure 2 shows the actual rate of moisture removed from green tea leaves, compared with the moisture absorption capacity of air supplied by a withering fan, to the experimental troughs of size 70' x 6' (21.34 m x 1.83 m) loaded with 1050 kg of green leaf. The moisture absorption capacity is the theoretical estimate, assuming that inlet air can absorb moisture until it got saturated.

Although there are other parameters, which govern the moisture removal, such as free area available for evaporation, surface film coefficient, Figure 2 clearly illustrates that the amount of air supplied for withering is more than the required quantity. This indicates that there is potential for reduction of airflow and such reduction invariably leads to energy saving.

Air volume regulation of withering fans

Airflow of withering fan can be controlled by outlet damper, inlet guide vanes or by speed adjustment. Out of these flow control methods, the most efficient is the method employing variable motor speed control system. To study the effect on regulating the air flow, a variable speed drive was installed in one of the withering

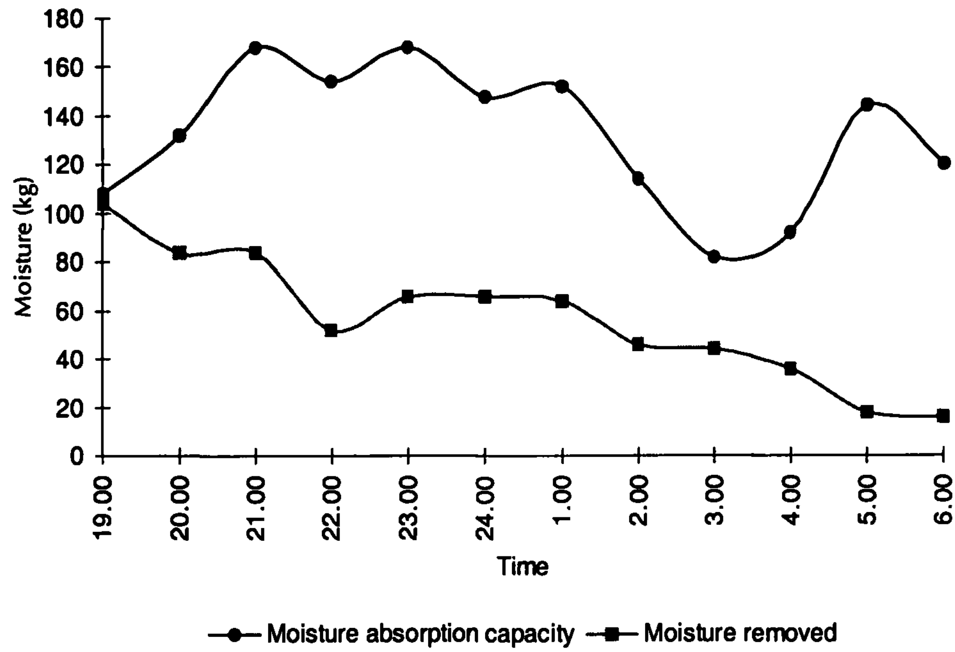

Figure 2: *Actual amount of moisture removed and moisture absorption capacity of air supplied to the trough, with time*

troughs at St Joachim Estate, Ratnapura and several trials were carried out in order to verify this phenomena.

The power requirement of the fan is proportional to cube of the speed, whilst the flow reduces linearly and pressure reduces as the square with the speed reduction.

Trial 1:

Fresh green tea leaves were spread evenly, fan motor was started and leaves were loosened. After about 4 hours of operation of the withering fan, inlet airflow rate was reduced by about 30%, by regulating the fan speed. Airflow rate was further reduced by about 15%, after 7 hours of operation of the fan. The reduced flow rate was maintained until the required wither is achieved. Figure 3(a) shows the variation of airflow rate during the withering operation.

Dry bulb and wet bulb temperature difference of the inlet air in the control as well as experimental trough was maintained at comparable levels. Fig 3 (b) shows the variation of dry bulb and wet bulb temperature difference during the trial, in a particular trough.

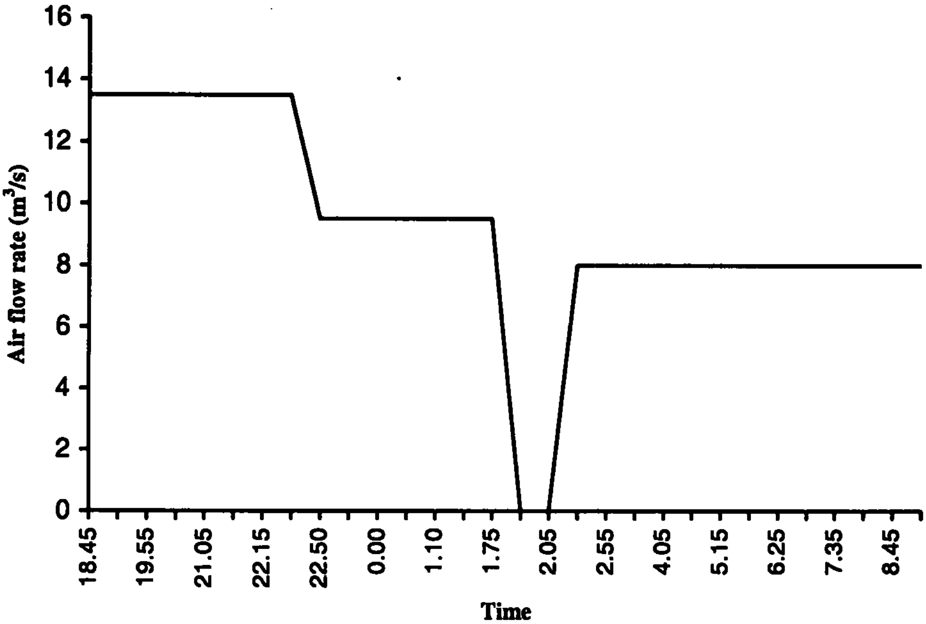

Figure 3(a): *Variation of airflow rate*

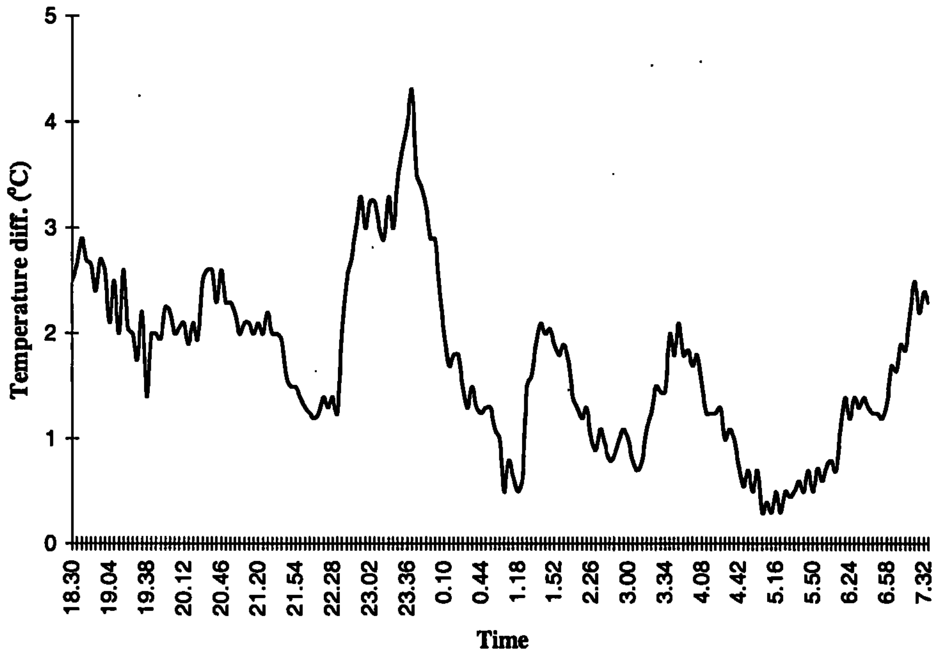

Figure 3(b): *Variation of dry bulb and wet bulb temperature difference*

Power consumption of the fan motor was monitored and recorded continuously. A power analyzer cum recorder was used for this purpose. In order to cross check the records of the power analyzer, a conventional three-phase kWh meter was connected in series with the power analyzer. Figure 3 (c) shows the variation of power consumption due to regulation of the airflow.

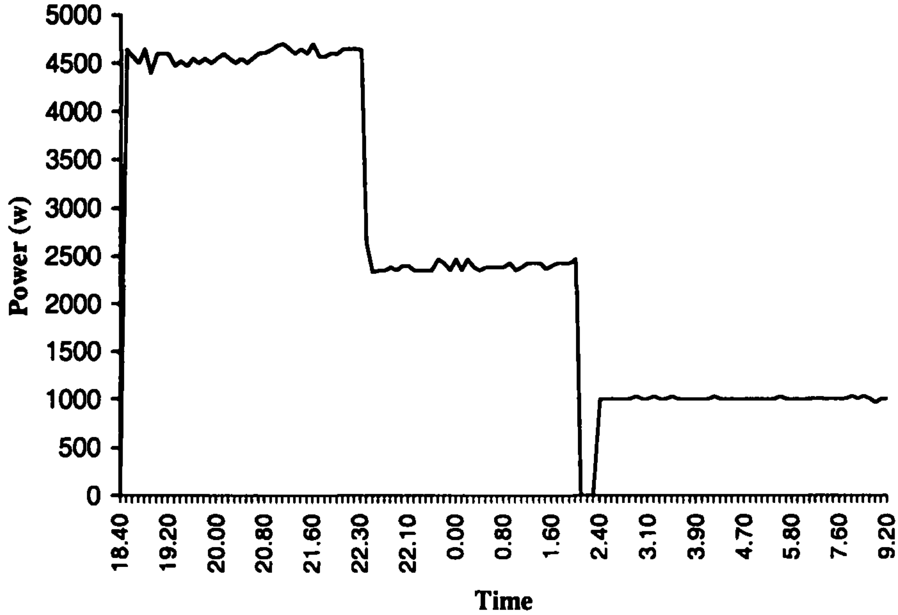

Figure 3(c): *Power consumption by the motor*

Chamber pressure was monitored during the process to make sure that there is a uniform flow of air through the leaf bed. The total green leaf weight and the withered leaf weight (once the wither was complete) were also recorded. Same test was repeated on the following day.

Trial 2:

From Trial 1, it was realized that there was no effect on the final moisture content, if airflow is reduced, four hours after the commencement of the withering operation. Therefore, Trial 2 was planned for further reduction of airflow from beginning of the withering process.

During this trial green tea leaves were spread, fan motor was started and leaves were loosened. Airflow was reduced immediately after starting the motor and it was further reduced after about 7 hours of operation of the fan motor. Fig 3 (d) shows the variation of power consumption due to regulation of motor speed.

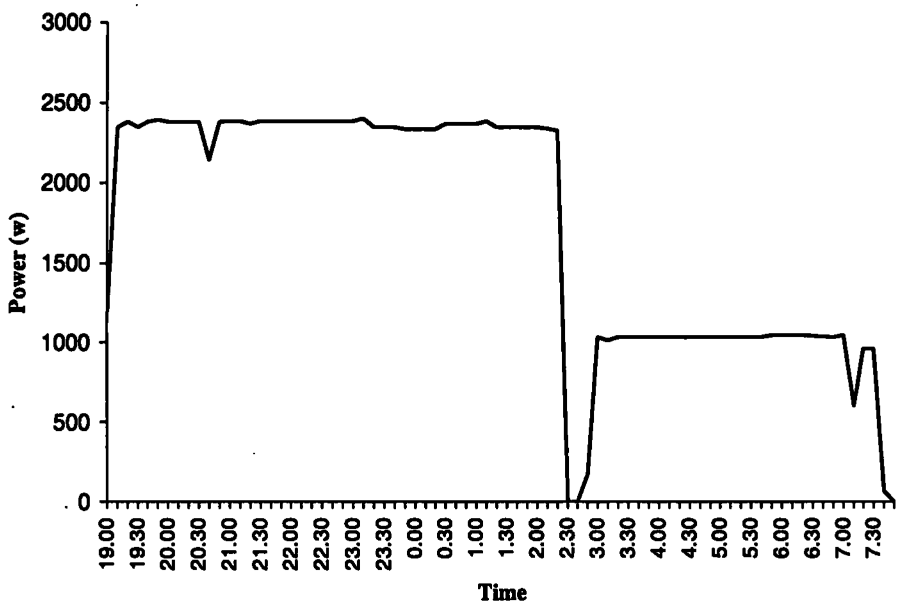

Figure 3(d): *Variation of power consumption with time*

Same test was repeated for another four consecutive days. Results are summarized in Table 2 below:

Table 2: Summary of test results

Date	Trial 1		Trial 2				
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Green leaf loading rate kg/m²	2.6.9	26.9	26.9	26.9	26.9	26.9	26.9
Withering time (hrs:mins.)	14.00	13.30	12.00	15.00	16.00	14.15	14.00
Specific energy consump. (kWh/kg MT)	0.144	0.138	0.097	0.108	0.146	0.106	0.099
Initial moisture content (%)	78.07	79.31	77.57	78.80	79.70	78.11	77.69
Final moisture content (%)	65.72	65.15	64.55	68.40	68.42	65.47	68.24

Energy consumption for the withering process was monitored in the same trough without making any alterations and results are shown in Table 3 below:

Table 3: Specific energy consumption for withering process

Green leaf loading rate kg/m^2	26.9	33.8	26.9
Withering time (hrs:mins.)	13.10	15.15	11.35
Specific energy consumption (kWh/kg of MT)	0.316	0.256	0.241
Initial moisture content (%)	74.01	77.70	80.00
Final moisture content (%)	65.10	65.32	65.68

Lower power consumption of 0.246 - 0.316 kWh/kg MT in a normal trough, compared to 0.46 kWh/kg MT cited in the literature, could be attributed to proper regulation of dry bulb and wet bulb temperature difference in the air supplied during trials. In an earlier study, it was observed that, regulating the dry bulb and wet bulb temperature difference in the inlet air alone, could result in a saving of about 17% of the electrical energy used for withering (Ziyad Mohamed, 1998).

CONCLUSIONS

Results from this study clearly show that the airflow rate required for withering process could be regulated according to the moisture removal rate of the green leaves. Up to 40% of electricity consumed in the withering process could be saved by proper control of airflow in the withering process by installing variable speed controllers, without affecting the quality of tea produced.

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