Thermal Energy Conservation in Kenyan Tea Processing Plants*

Einsparung von thermischer Energie in kenianischen Teeverarbeitungs-betrieben

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Red) Die Lösung von Energiefragen bei der Lebensmittelverarbeitung ist nicht nur in Industrieländern von Bedeutung. Der sinnvolle Energieeinsatz kann auch in Entwicklungsländern entscheidend für den Erfolg oder Misserfolg einer Technologie sein. Der vorliegende Beitrag diskutiert die Thematik am Beispiel einer kenyanischen Teefabrik. Aus der Arbeit lassen sich wiederum ganz allgemeine Gesichtspunkte der Möglichkeiten und Grenzen der Energieeinsparung im Lebensmittelbereich ableiten.

Ed.) Energy conservation in food processing is not only important in industrialized countries. It can likewise be decisive for success or failure of a technology in developing countries. The present contribution discussed this subject using Kenyan tea processing plants as an example. Of this investigation, general conclusion may be drawn on the possibilities and limits of energy conservation in the food industry.

1. Introduction

Kenya imports all her requirements of oil and coal. In 1985, for instance, the net oil import cost amounted to 32% of the total cost of the non-oil imports and 39% of the total non-oil export earnings. There ist thus a need to reduce the fossil fuel consumption in Kenya in order to alleviate the balance-of-payments problem. The manufacturing sector accounted for 24,0% and 30.5% of the total oil consumed in Kenya in 1980 and 1983, respectively. Oil conservation in this sector will therefore have a marked impact on the Kenyan oil import bill.

Tea processing is one of the major activities of Kenyan manufacturing industry. Marketed tea production increased from 119 000 tonnes in 1983 to 143 000 tonnes in 1986 and is expected to continue increasing as a result of the expanding tea acreage. It should be noted that tea as a foreign exchange earner in Kenya is surpassed by only tourism and coffee.

Energy is an important cost in a tea processing plant. Both thermal energy (fuel oil and wood fuel) and electrical energy are utilised. However, thermal energy consumption far exceeds electrical energy consumption. **Figure 1** shows the energy mix in thirty three Kenyan tea processing plants. Between 81% and 95% of the total energy consumption is in the form of fuel energy. It is therefore important to find ways and means of conserving thermal energy in tea processing plants.

Woodfuel is obtained locally and its use does not therefore have any influence on the balance-of-payments problem. The use of large quantities of wood in excess of the renewal rate would, however, lead to deforestation with its attendant adverse consequences. Furthermore, the woodfuel often has to be bought and its excessive use has a negative impact on the profitability of a tea processing plant. Because of these reasons, energy conservation is important even when woodfuel is the thermal energy source.

This paper concerns itself with thermal energy conservation in the production of black tea only. The steps involved in black tea manufacture are withering, rolling, fermentation and firing.

2. Thermal energy intensity in tea processing plants

Figure 2 shows the frequency distribution of monthly thermal energy intensity (GJ per tonne made tea) in thirty two Kenyan tea processing plants utilising only fuel oil as the thermal energy source. The lowest and highest values are about 11 and 37 GJ/t made tea, respectively. The average intensity is 19.2 GJ per tonne made tea.

Figure 3 shows the monthly variation of thermal energy intensity in four Kenyan tea processing plants. Plant B experienced the lowest variation, i.e. from 11.0 to 12.7 GJ per tonne made tea. At the other extreme, the monthly thermal energy intensity in plant A varied from 24.7 to 37.0 GJ per tonne made tea in the four months considered.

It is interesting to examine whether there is a relationship between the monthly thermal energy intensity and the monthly production of tea. As **Figure 4** shows, there appears to be no relationship between the two variables in the thirty two Kenyan tea processing plants over the period considered.

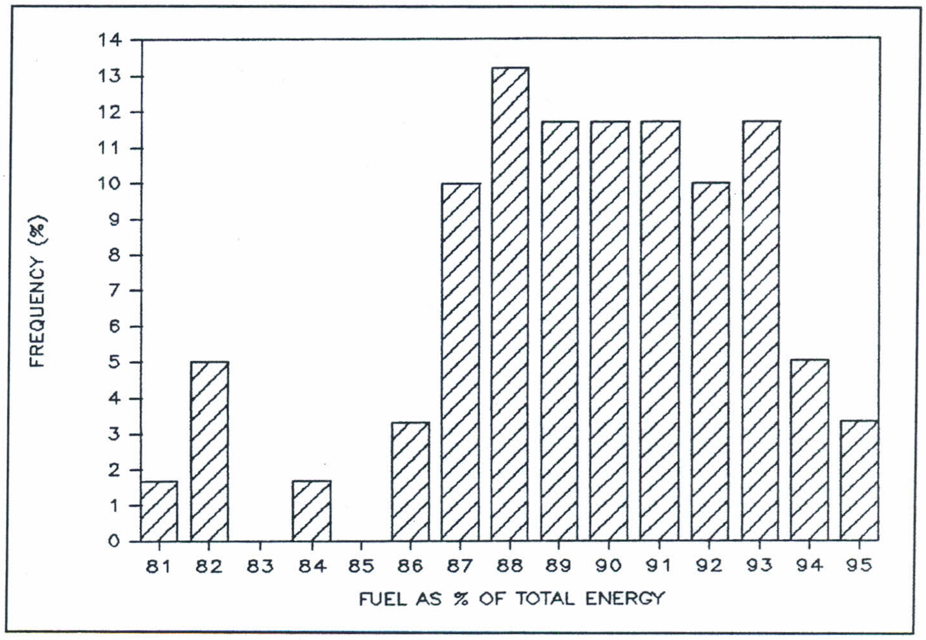

Fig. 1: Energy mix in thirty three Kenyan tea processing plants.

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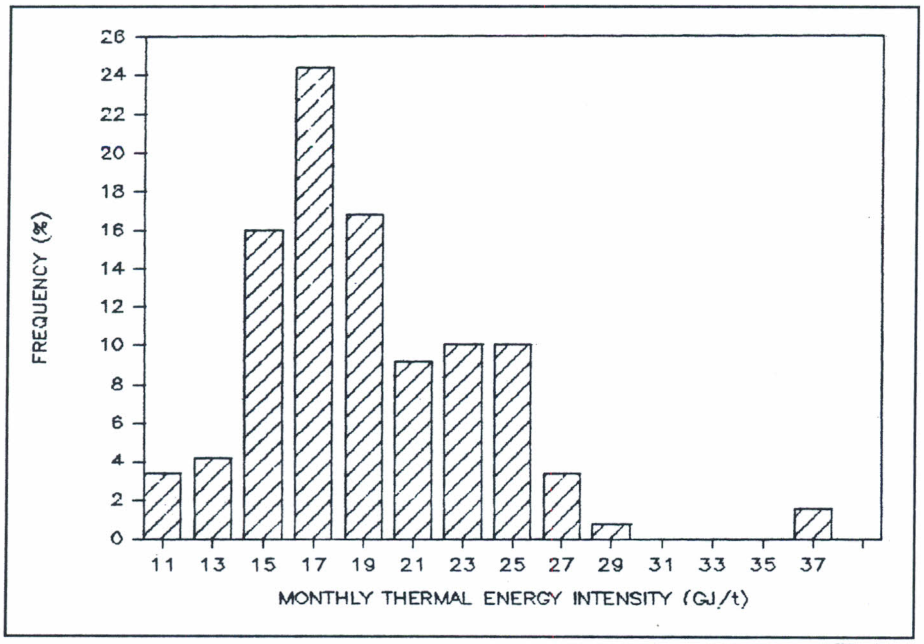

Fig. 2: Frequency distribution of monthly thermal energy intensity in tea processing plants.

There is no doubt that considerable potential exists for improvement of the efficiency of thermal energy utilisation in Kenyan tea processing plants.

3. Energy saving in thermal energy generation and distribution

3.1. Steam generation

In many cases steam generated in an oil-fired or wood-fired boiler is used to heat the air required for tea withering and firing (drying). Fuel saving can be obtained by improving boiler efficiency.

The type of boiler (Jennings, 1979) and its size (Ernst, 1976) should be correctly chosen to ensure high efficiency at all operating loads.

The use of an economiser to preheat the boiler feed water would result in fuel savings varying from 5 to 8% (Ernst, 1984). Payback periods of 1.5 to 2 years have been reported (Wilson, 1982).

Other fuel saving measures include proper maintenance and automatic control of blowdown and air to fuel ration (Ernst, 1974; Ernst, 1976; Ernst, 1984; Anon., 1982; Teck & Chen, 1979).

Where different fuels are available, the most economic fuel type should be used (Ernst, 1974; Stoeckl & Huck, 1979; Hamberger, 1982).

3.2. Steam distribution and condensate recovery

All steam and condensate pipes should be adequately lagged. Within economic limits, as much condensate, as possible should be returned to the boiler. Heat should be recovered as far as possible from condensate streams which cannot be returned to the boiler. Adequate steam traps should be provided and maintained to minimise steam losses. Condensate tanks should be adequately lagged. Leakage of steam and condensate should be avoided. All these, and other, measures necessary to minimse energy losses in the steam and condensate systems have been discussed in the literature (Spirax Sarco GmbH, 1981; Ernst, 1984; Gibson, 1965).

3.3. Indirect fuel oil air heaters

Indirect fuel oil air heaters are used in some Kenyan tea processing plants. In these heaters, there are separate flow passages for drying air and combustion gases. Their economic operation requires the attaining of high combustion rates with low percentages of excess air, avoidance of black smoke, and long refractory life (Masters, 1976). These conditions can be fulfilled if atomisation is complete, mixing of oil spray and air is intimate and oil flame does not contact refractory within heater. It is emphasised that the external surfaces of the air heater should be properly lagged to minimise heat losses by convection and radiation. The possibility of recovering heat from the flue gases in order to preheat the incoming drying air is worth investigating.

4. Energy conservation in tea drying

4.1. Withering

Withering refers to low temperature partial drying of fresh tea leaf prior to rolling. The common method is to pass warm air through a layer of tea leaves on hessian or nylon netting supported on a wire mesh placed in the upper part of a trough. The air temperature is kept low in order to retain the activity of the enzymes responsible for the desired changes during the subsequent fermentation process. Air heating occurs either by means of steam or by means of indirect fuel oil heaters.

Fresh tea leaf has a moisture content of 76–77% which may vary depending on the cultivation conditions, season, mode of plucking, etc. (Bokuchava & Skobeleva, 1980). Bokuchava and Skobeleva (1980) reported the moisture of withered tea to be 62–64% although Codd et al. (1975) indicated values varying from 45 to 70%.

The low drying temperatures result in fairly low thermal energy losses by convection and radiation from the surfaces of the drying troughs which may not justify elaborate thermal insulation. An optimum combination of operating parameters such as drying air temperature, drying air flow-rate, thickness of the leaf layer and drying time which results in low energy consumption without impairing product quality should be arrived at. Reliable process control systems would ensure that these variables do not deviate appreciably from the optimum levels.

Finally, serious consideration should be given to the possibility of utilising solar energy to provide at least part of the thermal energy required for heating the air for withering.

4.2. Firing

The final drying process after the tea leaf has undergone fermentation is usually referred to as firing. The fermented tea at 58–60% moisture content is dried to 3–4% moisture content by bringing it into contact with a stream of hot air (Bokuchava & Skobeleva, 1980). Two types of tea driers are in use in Kenya, namely, endless chain and fluidised bed drier.

4.2.1. Endless chain drier (ECD)

In this type of drier, the tea leaf is on a series (usually 4) of slowly moving perforated trays placed one above the other. The fermented tea is fed at one end of the top level tray and moves to the other end where it falls to the next lower level tray and the process is repeated until the tea is discharged from the drying chamber, at the end of the lowest tray. Heated air is fed in at the bottom of the tray assembly and flows upwards through the layers of drying tea leaf, finally discharging to the atmosphere after passing through the top layer of tea. Countercurrent flow thus occurs with the driest tea leaf on the bottom tray being in contact with the hottest incoming air and the most moist tea leaf on the top tray being in contact with the lowest temperature air.

Eden (1976) reports that inlet air temperatures usually range from 82 to 94 °C although Karigi and Kihara (1979) found figures ranging from 104 to 110 °C in Kenyan tea processing plants. Harler (1963) re-

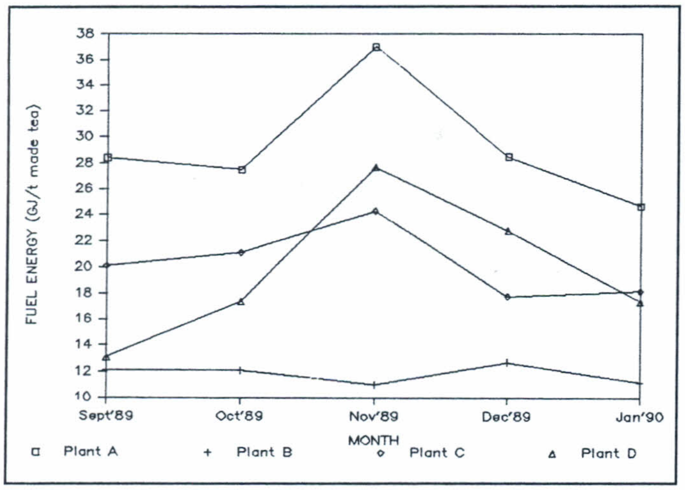

Fig. 3: Monthly variation of thermal energy intensity in four Kenyan tea processing plants.

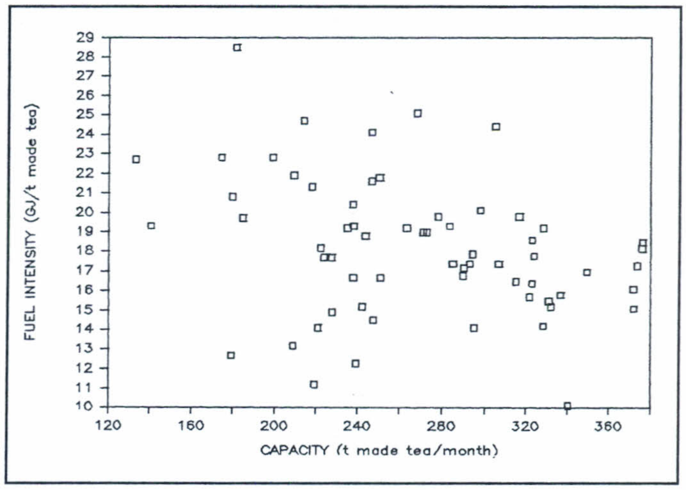

Fig. 4: Relationship between the monthly thermal energy intensity and the monthly production of tea.

commends that the exhaust air temperature be maintained at 48.9–54.4 °C.
The following measures would result in decreased thermal energy consumption:

(1) Insulation of the external surfaces of the drying chamber.

(2) Strict control of the inlet air temperature.

(3) Recirculation of some of the exhaust air.

(4) Avoidance of over-drying.

4.2.2. Fluidised bed drier (FBD)

In this drier, a layer of tea in a drying chamber is fluidised by passing hot air through it from bottom upwards a ta suitable velocity. There is thus intimate contact between the air and the tea particles resulting in efficient, uniform drying. There are usually two or more drying sections, each of which is supplied with a separate hot air stream. In one Kenyan FBD, for instance, the first section has an air inlet temperature of 140–150 °C and an exhaust air temperature of 30–40 °C while the second section has an inlet temperature of 100–120 °C and an exhaust temperature of 60–70 °C.
All the energy saving measures recommended in Section 4.2.1 are also valid for fluidised bed driers. In addition, there exists the possibility of recovering heat from the exhaust air and using it to preheat the incoming air.

5. Concluding remarks

Kenya produces a large and increasing quantity of black tea. Thermal energy in the form of fuel oil and woodfuel is used in a large quantity in Kenyan tea processing plants. The thermal energy intensity in individual plants varies widely. There is considerable potential for saving thermal energy in Kenyan tea processing plants.

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