ASSESSMENT OF MECHANICAL HARVESTING OF TEA AND ITS VIABILITY FOR USE IN KENYA

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Abstract
Harvesting of tea (*Camellia sinensis*) involves the removal of the tender, growing shoots from the surface of the tea bush. Two processes exist for harvesting tea: coarse plucking and fine plucking. In fine picking only a bud and the second and third leaves are picked while for the coarse plucking more leaves are picked with the bud. For a long time tea harvesting has been carried out by hand but in the recent years most tea producing countries including India, Japan, China and Papua New Guinea have adopted the use of machines. A review of published research work indicates that chemical quality parameters of black tea change with the method of harvesting. Hand-plucked teas are rich in their green-leaf biochemical precursors and have higher contents of made-tea quality constituents than machine-plucked teas. Quality deterioration is mainly due to mechanical injury and non-selective plucking with shear-harvesting. The use of machines increases the plucking average with a net decrease in cost of production compared to hand plucking. An economic analysis carried out in this study proved that mechanized harvesting of tea is viable for adoption in most Kenyan plantations. To avoid quality deterioration, it is recommended that mechanized tea harvesting should be undertaken mainly during the peak production period.

Key words: Yield, quality, biochemical precursors

1.0 Introduction

Black tea is the cheapest non alcoholic stimulant taken throughout the world and is manufactured from the tender shoots of *Camellia sinensis* which is grown in some tropical and temperate countries (Hampton, 1992). The profitability of the operation is governed by the quantity and quality of the plucked shoots (Mamedor and Dzhafarof, 1974; Baruah *et al*., 1986; Obanda and Owuor, 1995).

The frequency of harvest depends primarily on the temperature, the incidence of drought, and the shoot standard (number of unfurled leaves per shoot) as specified by the processor for an identified market. Traditionally, in most developing countries, harvesters (often locally known as "pluckers") remove the shoots (typically two or three unfurled leaves and the unopened terminal bud) by hand. This can be a selective and skilful process involving between 140 and 190 individual hand actions per minute (Evans, 1993). In Southern Tanzania, pluckers typically remove between 4 and 9 kg of fresh shoots per hour depending on peaks and troughs in production (Squirrell, 1995). This represents 1700-5000 person hours ha-1 for a crop with an annual yield of 15-20 t ha-1 of fresh shoots. Labor on commercial estates, although cheap in absolute terms, currently represents 40–45 % of the total field costs when the provision of housing and other social benefits are included (Burgess, *et al*., 2006). In some areas, there is also a shortage of men and women willing to undertake this repetitive work on a continuing and reliable basis. Strategically, there is also the need to plan for a declining workforce because of the high incidence of HIV/Aids in many of the tea producing regions of Africa (Burgess, *et al*., 2006).

So far, tea leaves are harvested by hand-plucking without causing mechanical injury and manufactured under optimum conditions in order to maintain quality (Owuor *et al.,* 1987). Due to the sharp rise in labor costs and the ever increasing cost of production most tea industries are becoming almost non profitable. Thus with this changing economic scenario, scientists have been asked to enhance profitability. This has lead to partial mechanization of shoot harvesting using hand operated shears. This process increases the rate of plucking and reduces the manpower involved (Otieno and Anyuka, 1982).

As well as influencing the yield and quality characteristics of the harvested crop, the method of shoot removal can affect the number, size and type of shoots remaining on the bush. For example where tea is grown at relatively high temperatures in Malawi and Assam, plucking immature shoots can limit yields (Tanton; 1979; Manivel and Hussain, 1986) and some form of selectivity, as practiced by skilled pluckers, is important for bush productivity. It can also affect the quality of the harvested crop, which can be defined in various ways. At the tea factory gate, the harvested shoots are often judged on the basis of the composition of a sample of shoots, including shoot size distribution and the proportion of broken shoots and coarse material (Burgess,*et al.,* 2006). After manufacture the processed tea leaves and resultant tea liquor are judged and valued, depending on the market, by sensory characteristics such as color, brightness, briskness and flavor.

Evaluating the effectiveness of different tea mechanical harvesting systems therefore requires several parameters to be assessed. These include yield, the composition of the harvested shoots, the value of the processed tea, the frequency and intensity of harvesting in relation to stages of bush and shoot development, long-term effects on the vigor (productivity) of a bush, ease of use including height control, maintenance, labor productivity, and economics. To complicate matters further, clones which are multiplied through vegetative propagation differ in the morphological characteristics of the shoots. This in turn may influence their suitability for mechanical harvesting (Burgess, *et al*., 2006).

The information currently available on mechanical harvesting comes from industries covering a wide range of conditions. The environment influences the growth characteristics of the tea bush and the way it is managed, for example three to four plucking rounds are required in a season in Japan but between 16 and 25 are required in Kenya (Nyasulu 2001).

Assessment of yield and leaf quality from mechanical plucking needs to be done. There is some evidence that a greater proportion of maintenance and immature shoots are harvested during mechanical plucking as compared to hand plucking (Obanda and Owuor, 1995). The objectives of this study were to assess the effect of mechanization on harvested tea quality and assess the viability of replacing manual harvesting with machines.

2.0 Mechanized Harvesting and Tea Quality

Harvesting involves the removal of tender, growing shoots from the surface of the bush. A horizontal 'plucking table' surface of mature 'maintenance' foliage is preserved, so that new shoots project above the surface and are easily removed. The harvested shoots are then processed in various ways to make green or black tea (Chandra and Onsando 2006). With mechanical plucking, most tea quality parameters decline. Ravichandran and Partiban (1998) found that the theaflavin and caffeine content for machine harvested leaves was lower than the quantity in handpicked leaves (Table 1). They also found that the contents of thearubigins, which are undesirable beyond a certain value, increased with machine harvesting. The taste of hand plucked tea was better than that of machine harvested tea (Table 1). There is need for research to develop strategies for improving the quality of machine harvested tea leaves.

Table 1: Quality of hand and machine plucked tea (Ravichandran and Parthibann 1998)

Tea quality parameters	Hand plucked	Machine plucked
Theaflavins %	0.78	0.67
Thearubins %	7.60	8.10
Caffeine %	3.30	3.00
Tasters score	33	25

2.1 Economic Analysis of Tea Harvesting in Kenya

In 2006 the area under mechanization, in Kericho District, consisted of 694 ha (Table 2). The main tea producers include James Finlay Ltd which has mechanized tea harvesting in 600 ha. Unilever Tea Ltd has 54 ha of tea with mechanized harvesting while Sotik tea 40 ha (Bore, 2009). The area under mechanized harvesting is approximately 2.3 % of the area under tea. The adoption of mechanized tea harvesting is on the rise with large companies using machines in most of their tea estates. Various types of machines have been developed from hand held single man machines, through rickshaw machines pulled by two operators to large self propelled harvesters. The success of machines has varied as much as the design of the machines themselves. Growers require information on how to manage tea bush under mechanical harvesting including practices such as plucking rounds, table height rise and pruning cycles (Nyasulu, 2001).

Hand-held machines are being used by several estates, either carried by a single operator or by a team of two. These are particularly suited for use on hilly terrain where wheeled harvesters are not practical. A common complaint about this type of machine, however, is that it is difficult to maintain a good table with it because operators tend to carry the machine at a convenient height rather than at the required table height. When carried too low, the maintenance leaf is plucked, thereby reducing the tea quality (Obanda and Owuor, 1995).

Table 2: Distribution of tea area under different harvesting methods in Kericho District

Method of harvesting	Area (ha)
Mechanized	694
Manual	29480
Total	**30174**

Although mechanization of tea harvesting is recognized as a realistic option for cost reduction, there is need for interventions to ensure that mechanization becomes a reality in Kenya's tea industry. In this study an economic analysis was undertaken to assess the viability of mechanized tea harvesting.

Table 3: Technological detail assumptions

A hand operated tea harvester was available at the cost at most Ksh 100,000
The machine had the capacity is 1 ha per day, or 6000 kg per day
Each harvester requires two operators
Rate of discount is 12%
Running cost was mainly the cost of fuel
One liter of petrol was enough to harvest 500 kg
The price of petrol was Ksh 120 per liter
Labor cost was Ksh 200 per day
Rate of manual tea harvesting is 25 kg/person/day
There is need to make major machine repairs during the third year of operation
Cost of major repairs is 10% of initial cost of the machine (Ksh 10,000)
The salvage value of the machine is Ksh 5,000
Farm size is 12 ha
It is possible to lease out machine for 100 days in a year
The farmers would be willing to pay machine harvesting fee of Ksh 5/kg of tea leaves
The selling price of unprocessed tea is Ksh 62 per kg
Borrowing rate from the bank is 18%

The discounting factor (DF) is used to determine how much one unit at a future date is worth today. It was calculated according to equation 1:

$$DF = (1 + r)^{-T} \quad \text{..... (1)}$$

Where r = the discounting rate and T = time period (year). The discounting rate is the interest rate at which future values are discounted to the present. It is usually close or equal to the prevailing borrowing rate (opportunity cost of capital).

The economic life of a piece of equipment is the period during which fixed asset is capable of yielding services to its owner and as such worthy keeping in use. In this study it was assumed that the economic life of a tea harvester was 5 years, after which period the old machine would be sold as scrap for Ksh 5,000. It was also assumed that the harvesting machine was bought on loan with an interest rate of 18%. Using the capital recovery factor, the annual repayment rate was calculated as Ksh 31,978.

The capita recovery factor (crf) is the annual payment that will pay a loan of one currency unit in a given period with compound interest on the unpaid balance (World Bank, 1986). It is equal to the reciprocal of the annuity factor. The annuity is an amount paid annually for a stated period of time. The crf permits calculation of equal installments necessary to repay a loan over a given period.

Present value (PV) is the cash equivalent now of a sum of money receivable or payable at a stated future data discounted at a specified rate of return. Discounting converts a future value to a present value.

$$PV = FV.DF = FV\frac{1}{(1+r)^T}$$

The discount factor (DF), is the reciprocal of the compounding factor for one unit, and FV is the future value, which is the net cash flow. The net present value (NPV) is the value obtained by discounting all cash outflows and inflows of a capital investment project by a chosen target rate of return (BPP Leaning Media, 2009). Using manual harvesting of tea, the NPV of the cash flow for the economic life of 5 years was calculated as Ksh 13,799,083. For machine harvesting, the NPV was Ksh 25,390,438. Therefore, the money made per kg of tea harvested was calculated as Ksh 38 for manual harvesting and Ksh 72 for machine harvesting.

Table 3: Discounted cash flows for manual harvesting

Manual Harvesting						
Cash flow description	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Working gear		(60,000)	(60,000)	(60,000)	(60,000)	(60,000)
Labor cost		(576,000)	(576,000)	(576,000)	(576,000)	(576,000)
Sales		4,464,000	4,464,000	4,464,000	4,464,000	4,464,000
Net cash flow	**-**	**3,828,000**	**3,828,000**	**3,828,000**	**3,828,000**	**3,828,000**
Discount rate = 12%						
DF	1.00000	0.89286	0.79719	0.71178	0.63552	0.56743
PV	-	3,417,857	3,051,658	2,724,695	2,432,763	2,172,110
					NPV	**13,799,083**

From the financial analysis done, mechanized tea harvesting is clearly more profitable than manual tea harvesting. Because of the fear of losing jobs, workers unions in the tea estates have been opposed to mechanization in the tea industry. It is necessary that the concerned government departments do whatever is necessary to enhance the profitability of tea farming perhaps through legislation, provision of guidelines and providing an appropriate mechanization policy. Workers who have been opposed against mechanization for fear of losing their jobs should be given assurance that mechanization will only make things better for them. It is worthy giving local industries incentives to encourage them to manufacture tea harvesting equipment for use in the country (Tsoutsos *et al.,* 2003).

Table 4: Relevant discounted cash flows for machine harvesting

Cash flow description	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
crf at year 5						0.3198
Machine cost	(100,000)					
Scrap value of machine						5,000
Loan payment (for r=18%)		(31,978)	(31,978)	(31,978)	(31,978)	(31,978)
Working gear		(2,000)	(2,000)	(2,000)	(2,000)	(2,000)
Labor cost		(224,000)	(224,000)	(224,000)	(224,000)	(224,000)
Fuel costs		(161,280)	(161,280)	(161,280)	(161,280)	(161,280)
Replacements				(10,000)		
Sales		4,464,000	4,464,000	4,464,000	4,464,000	4,464,000
Machine leasing income		3,000,000	3,000,000	3,000,000	3,000,000	3,000,000
Net cash flow	**-**	7,044,742	7,044,742	7,034,742	7,044,742	7,049,742
Discount rate = 12%						
DF	1.00000	0.89286	0.79719	0.71178	0.63552	0.56743
PV	**-**	6,289,948	5,616,025	5,007,191	4,477,061	4,000,213
					NPV	25,390,438

There are several modifications that have to be made to fields to allow the use of wheeled harvesting machines. A considerable amount of time has to be spent clearing branches and other obstacles between the tea rows to allow free passage of the machines and to clear headland areas for turning. Consequently, the best time for bringing a

field into mechanical plucking is following pruning. Some leveling of the inter-rows is also necessary to avoid erratic changes in table height when the machines are used. The removal and the trimming of the back of bushes obviously results in reduced production, but this has not yet been quantified. (Nyirenda 1995).

3.0 Conclusion

(i) The quality of black tea decreases with machine harvesting both in terms of liquor strength and quality constituents. This is thought to be because the selectivity of the tender shoots is lost when machine harvesting is used.

(ii) The leaf yield from machine harvesting is greater than that of hand harvesting and production costs also decrease with adoption of machinery.

(iii) The most suitable machines for adoption in Kenya are the two man held machines as they do not require restructuring of the plantation layout.

(iv) Tea production cost reduces with the introduction of machine harvesting and the Net Present Value of machine harvested tea is twice as much as the NPV of hand picked tea.

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