J. Rubb. Res Inst. Malaysia, 31(1), 1–4

Determination of Calorific Values and Energy Content in Hevea *Trees*

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This paper presents the method by dry weight sampling and use of an oxygen bomb calorimeter to determine the calorific values and energy content in mature rubber trees. Values obtained varied with differenι plant components and clones of Hevea. *Further work with the bomb calorimeter is envisaged.*

The method of determining the heat of combustion by means of an oxygen bomb calorimeter has been adapted to plant studies of energy relations and in ecological research[1,2,3]. Some aspects of energy flow in forest plantations have also been looked into[4,5] For a plantation crop such as rubber, there has been little work done to study energy content of the rubber tree, the wood of which has potential use as a fuel, besides other wood-based products such as sawn-timber, pulp and paper[6,7,8].

The method to determine calorific values and energy content in *Hevea* trees involves dry weight sampling and use of an oxygen bomb calorimeter.

MATERIALS AND METHODS

From a stand of rubber due for replanting, a destructive sampling of the mature trees growing on Rengam series soils was taken. The preparation of plant materials for the measurement of calorific values and energy content was as follows.

Preparation of Samples

Collection and drying of materials. Each harvested tree was separated into its various plant components and weighed in the field. Samples of the fresh material were brought back to the laboratory for dry-matter determination. In the laboratory, all samples were transferred into paper bags and dried in an oven at 75°C–80°C over a period of three days until constant weight was attained. The dried samples were weighed again, and the difference between fresh and dry weights allowed the conversion of the total fresh weights into dry weights.

The various components of the tree sampled for determination of calorific values included the trunk wood and bark, main-stem wood and bark, branch wood and bark, and, the leaves and petioles. For the determination of energy content in the two clones, RRIM 707 and RRIM 527, the bark of materials sampled were left intact. Six trees per clone were sampled for estimation of dry weight production.

Milling. The dried material must be homogenised before smaller samples can be taken for energy determination. This was done by milling and mixing the total sample into a uniform powder with a disk-type swing mill, the containers of which were completely closed, so that no dust would be lost or separated. The

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milled powder was transferred from the container into plastic bags and labelled with the sample number.

Preparation of Tablets

To measure the calorific values, compact units were formed from the powder as it was troublesome to weigh and process loose powder in a crucible. Units were prepared by compressing the powder into tablet form by a pellet press. Three combustion units of about 1 g each were prepared from each sample. The wire needed to ignite the tablet in the bomb was of a known calorific value. To prevent the tablets from absorbing atmospheric moisture, they were kept in a desiccator until required for use.

Preparation of the Oxygen Bomb

The preweighed tablet was placed in the oxygen bomb which is a heavy stainless steel container with a capacity of about 0.3 litre. It has a screw cap that contains all the necessary devices, such as inlet and outlet valves, terminals for the electric ignition, a holding device for a small stainless steel crucible or quartz cup, a shield to protect the upper part of the bomb against sparks and a rubber washer. The combustion unit was placed in the quartz cup and the two ends of the ignition wire attached to the electrodes. About 5 ml of water was poured to the bottom of the bomb and the bomb body slowly screwed to the cap. The closed bomb was then filled with 30 atm of oxygen through the inlet valve. The filled bomb was then ready to be placed in the water bath.

Preparation of the Water Bath

The water bath of the calorimeter was kept in a thin-walled kettle, which could be removed from the instrument. The kettle was filled with clean water up to a fixed mark. The temperature of the water was adjusted to about 19.5°C–20°C. The warmed bath was then taken quickly to a balance and the exact weight of 6 kg, calibrated from the very beginning for each pair of bomb and kettle, was adjusted. Immediately after weighing, the bath was placed in the calorimeter, the temperature probe inserted, and the necessary electrical connection made. The cover of the water jacket was closed and the Bechmann thermometer dipped through the cover into the bath. About 5 min was sufficient to bring the entire system to an even temperature. The whole apparatus was so constructed to secure adiabatic conditions within it, thus avoiding heat leakage and the consequent necessity for corrections.

The Measurement

When a stable temperature was obtained, the Bechmann thermometer was read. The ignition button was pressed and after about 10 min when there was no further increase of temperature, the highest constant temperature was read. The difference between the two readings, corrected by means of the calibration table for the Bechmann thermometer, was used for calculation of the calorific value. After the final temperature reading, the bomb was removed from the bath and the sample checked to ensure that it was totally burned. From the rise in temperature of the water and the grammes dry weight of plant material in the tablets used, the number of calories of energy involved was calculated.

Calculation of Calorific Value

The calorific value (V) of any sample is calculated from the formula:

$$V = \frac{W.\Delta t - \Sigma c}{G}$$

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where W is the water equivalent of the system

t is the corrected temperature difference reading of the Bechmann thermometer before and after burning

c is the correction value for the ignition wire

G is the sample dry weight.

The water equivalent of the system represents the amount of heat absorbed by the whole apparatus, including the water, per degree rise in temperature. It is found by combusting a standard substance of known heat value such as benzoic acid or succinic acid.

Calculation of Stored Energy

The total amount of stored energy was calculated from the determination of various components of one harvest. Estimates of the energy in the plant material was made by multiplying the calorific value by the oven dry weight of organic matter present per unit area.

TABLE 1. CALORIFIC VALUES OF PLANT MATERIAL

Plant material	Calorific value (cal/g)	
Leaves	5 000	
Petioles	4 654	
Trunk wood	4 479	±16.8 (50)
Branch wood	4 465	
Main-stem wood	4 430	
Trunk bark	4 375	
Branch bark	4 314	
Main-stem bark	4 264	

RESULTS AND DISCUSSION

Results of the calorific values of various plant components of the rubber tree such as the trunk wood and bark, main-stem wood and bark, branch wood and bark, leaves and petioles are shown in *Table 1.*

Results showed that the calorific values for the different types of plant materials sampled ranged from 4264 to 5000 calories per gramme of oven-dry matter. The leaves and petioles gave the greatest calorific values which agreed with observations made in other tree species[4,5] Among the other plant parts, wood tissues of the trunk, main-stem and branch gave greater calorific values than the bark tissues.

The energy content of trees in the two clones RRIM 707 and RRIM 527 is shown in *Table 2.* Results showed that the bulk of the energy is present in the trunk plus main stem with the remaining energy in the branches and leaves plus petioles. Between the two clones, the amount of energy present is greater in RRIM 707 than in RRIM 527. The differences in the amount of stored energy closely paralleled differences in the dry weight of trees between the clones. In terms of calorific values, RRIM 707 generally had greater values than RRIM 527.

CONCLUSION

The present study uses an oxygen bomb calorimeter to determine the calorific values and energy content of mature *Hevea* trees. Results have shown that the calorific values varied with different plant materials, with the leaves and petioles having the greatest values. Clonal differences in calorific values and energy content were detected. Bigger differences in energy content of the two clones studied were reflected by the differences in dry weight of the trees.

Arising from this investigation, future use of the bomb calorimeter is being considered to study to what degree the energy from photosynthesis is diverted to rubber synthesis as contrasted to the production of vegetative parts. In early empirical

TABLE 2. ENERGY CONTENT OF TREES FROM TWO CLONES

Plant part	RRIM 707			RRIM 527		
	Dry weight (10^3 g)	Calorific value (cal/g)	Energy content (10^8 cal/m^2)	Dry weight (10^3 g)	Calorific value (cal/g)	Energy content (10^8 cal/m^2)
Trunk plus main-stem	340.0	4 437	15.09	297.4	4 387	13.07
Branches	154.8	4 392	6.80	154.1	4 372	6.74
Leaves plus petioles	9.2	5 052	0.46	7.7	4 827	0.37
Total	504.0		22.35	459.2		20.18

studies, the rubber production efficiency of *Hevea* trees has been expressed as the ratio of the weight of dry rubber formed to total dry weight accumulation of the tree[9,10,11]. This was taken as an indication of the partition of assimilates between the two physiological pathways of growth and rubber formation. It will be useful to study partition of assimilates in clones of *Hevea* in terms of energy measured by the oxygen bomb calorimeter.

ACKNOWLEDGEMENT

The author wishes to thank the Director of the Rubber Research Institute of Malaysia, Dato' Haji (Dr) Ani bin Arope for permission to publish this paper which presents work carried out at the University of Ghent while the author was there on a Belgian Fellowship. Thanks are due to Prof. J. Schalck and his staff for the kind assistance rendered. The tree sampling was carried out at the RRIM Experiment Station and thanks are due to Dr Leong Wing and his research assistants for collecting the dry weight data. Thanks are also due to Dr P.K. Yoon, Head of Plant Science Division, for his useful comments.

Rubber Research Institute of Malaysia
Kuala Lumpur
September 1981

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