

Energy Input in the Production of Cassava

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Abstract

Energy is one of the largest components of the production cost in Agricultural activities. The efficiency of its use will often be compromised in favour of other equally important factors. Data were collected in 10 cassava farms by using face to face questionnaire method to determine the energy input in cassava production. Mathematical expressions were used to evaluate the energy requirement for each of the defined unit operations. Energy requirement in land preparation, planting, crop maintenance (fertilization and weed control) and harvesting were determined. It was observed that 78.67% of the total energy input used in cassava production was indirect, while 21.33% was direct. The average energy input in the production of cassava was 8571.26 MJ/ha, while 9960.00 kg was the average yield obtainable per hectare. Energy input in fertilizer was the highest with 64.0% of the total energy input; followed by diesel fuel with 19.50%. The net energy and energy productivity value were estimated to be 46,655.77 MJ/ha and 1.18 MJ/kg respectively. The ratio of energy output to energy input was 7.1.

Keywords: Energy, cassava, renewable fuel, energy ratio, energy productivity

1. Introduction

Agriculture is both a producer and consumer of energy. It uses large quantities of locally available noncommercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production, productivity and contributes to the profitability and competitiveness of agricultural sustainability in rural living (Singh *et al.*, 2002).

Energy inputs of different forms in agricultural production in almost every country are on the high levels. The reduction of these inputs by using agricultural products and residues as renewable energy sources is and will remain an important issue in future. It is closely related to the environmental problems arising from agricultural production on large surfaces. Therefore, the rational and efficient use of energy is essential for sustainable development. Chamsing, *et al.*, 2006 in their work on some crops stated that for irrigated rice, rainfed rice, maize, wet-season soybean and cassava, energy input varied between 1.79-18.49, 10.09-13.11, 9.79-12.79, 5.21-10.03 and 4.95-9.13 GJ/ha respectively. They also observed that about 62% and 38% of energy inputs in farm operations was from indirect and direct energy inputs respectively. Energy from fertilizer contributed the highest followed by energy from seed, pesticide and herbicide.

Average energy ratio of selected crop production of Thailand was 5.20. This ratio is higher than the ratio of Turkish (1.18) in crop year 2000 (Ozkan *et al.*, 2004) but lower than the ratio of Bangladesh (8.11) in crop year 2000/01 (Alam *et al.*, 2005). Energy ratio for rice, maize and sugarcane production were depended on area and were nearly of the same range as India which were 2.15-12.75 for rice, 4.83-17.02 for maize and 5.82-6.67 for sugarcane production (Singh *et al.*, 1997).

Both direct energy use for crop management and indirect energy use for fertilizers, pesticides and machinery production have contributed to the major increases in food production seen since the 1960s (Woods, 2010). However, the relationship between energy inputs and yields is not linear. Low-energy inputs can lead to lower yields and perversely to higher energy demands per tonne of harvested product. At the other extreme, increasing energy inputs can lead to ever-smaller yield gains.

Cassava (*Manihot esculenta*) is a perennial woody shrub with up to 32% (fresh) starch content which is cultivated extensively as a food crop in Africa, is the third largest source of carbohydrate in food for human consumption in the world. Cassava roots play an important role in the African diet and they are processed, using

simple traditional methods, into products such as *Gari*, *Fufu* and *Lafun* flour. It is estimated that about ten million tonnes of cassava is processed for *Gari* annually in Nigeria alone. Because of recent characterization of cassava starch properties, market demand for cassava for the production of starch-based products has increased rapidly. This has led to an increase in the cassava growing area, which has reached about 500,000 ha in the past two years. Cassava production system is also changing from being a small-scale subsistence crop to a large-scale commercial crop. This paper determines the energy requirement in the production of cassava in each of the stages of production. This involves land preparation, planting, crop maintenance (fertilization and weed control) and harvesting.

2. Materials and Methods

Ten farms were surveyed to collect data on fuel, natural gas, fertilizer, pesticides and chemicals used on the farm for cassava production. The areas of study covered Oyo, Ogun, Osun and Kwara States of Nigeria. Four farms were surveyed in Oyo States, while two farms were surveyed in Ogun, Osun, and Kwara states respectively. The data for energy input resources in all the selected farms during cassava production from land preparation to transportation to the market or house was collected using structural questionnaire and oral interviews. The information obtained was extracted personally from the available documents in the surveyed areas. The input energy was divided into direct and indirect energy. The direct energy consists of diesel, human power and electricity, while the indirect energy contains seeds, fertilizers, farmyard manure, chemicals and machinery.

3. Processing Technology and Method of Energy Evaluation of Cassava Production

The type and magnitude of the energy consumed is a function of the process and the technology employed. In order to quantify the energy demands of each unit operation, quantitative data on operating conditions was required for each unit operation. Table 1 summarizes the production technologies under study of the cassava production.

Table 1. Measured Parameters for Evaluating Energy Input in Cassava Production

S/N	Operation	Required Parameter
1	Land preparing	Time taken for preparing the land, h Number of person involved Fuel consumed, l Calorific value of fuel used, J/l
2	Stem harvesting	Time taken for preparing the stem, h
3	Planting	Number of person involved. Time taken to plant the stem, h
4	Herbicide application	Number of person involved. Time taken to apply the herbicide, h
5	Fertilizer application	Number of person involved. Time taken to apply the fertilizer, h
6	Inter – row Weeding	Number of person involved. Time taken for the weeding, h
7	Harvesting	Number of person involved. Time taken for the harvesting, h
8	Transportation	Number of person involved. Time taken for the harvesting, h

The types and magnitude of the parameters required for the energy evaluation of each unit operation are presented in Table 2. Jekayinfa and Bangboye (2005, 2006) used similar procedure in the energy audits of palm-kernel oil mills and cashew-nut mills in Nigeria.

Table 2. Production Techniques at Each Stages of Production of the Cassava

S/N	Operation	Equipment and Principle Adopted
1	Land preparing	Mechanized. Tractor 4W, Disc plow Disc harrow Ridger
2	Stem harvesting and Gathering	Manual with the use of Cutlass
3	Planting	Manual with the use of cutlass.

4	Herbicide and Pesticide Application	Manual knapsack sprayer. Boom sprayer-hydraulic
5	Fertilizer application	Manual
6	Inter – row Weeding	Manual with the use of cutlass.
7	Complete Harvesting	De-stumping Manual
	De-stumping axe or machete	Use of truck
	Transportation	Transportation to factory, Tractor 4W – Trailer

The energy evaluation methods for each unit operation are as follows.

Land Preparation

Initial land clearing of field was done using tractor coupled with a disc plow for primary tillage, while secondary tillage was done using a disk harrow or rotary tiller. The time and fuel consumed by the tractor per hectare during each stage was obtained and used to compute the energy. The energy consumed for land clearing was obtained from the expression:

$$E_{lp} = 47.8 D + 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (1)$$

Where

D = Amount of diesel consumed per unit operation, L.

0.075 = Energy input of an average adult male, MJ/h.

$T\alpha$ = Useful time spent by a male worker per unit operation,

N is the number of persons involved in an operation

Stem harvesting and gathering

The amount of bundle required for planting one hectare, the time and the number of people required was obtained from the farmer and was used in the computation of the energy. The energy consumed was obtained from the expression:

$$E_{shg} = 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (2)$$

Planting

The amount of time required for planting and the number of people that performed the operation was obtained from the survey and used in the computation of the energy. The energy consumed was obtained from the expressing:

$$E_p = 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (3)$$

Pesticide Application

Pre emergence herbicide spraying was done using a tractor-mounted boom sprayer immediately after the planting operation in some farms. While both pre emergence herbicide spraying and post emergence herbicide spraying was done manually in most of the farms with knapsack sprayer in the farm surveyed. The amount of fuel used, time consumed, number of people involved in the operation, and amount of the pesticide and herbicide used was obtained through the questionnaire during the survey. The energy consumed was obtained from the expression:

When the operation is carried out manually

$$E_{hva} = 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (4)$$

Pesticide energy input (MJ/ha)

Total pesticide input (MJ/ha) = $P_{app} \cdot P_{ev}$

P_{app} = Applied rate (kg or lit/ha) of pesticide 1th for applied time

P_{ev} = Energy equivalent MJ/kg or litres of pesticide

When tractor-mounted boom sprayer is used

$$E_{hva} = 47.8 D + 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (5)$$

Fertilizer Application

This is done manually in all farms considered. The time required by the farmers to apply the fertilizer, the number of people that applied it, and quantity of fertilizer used per hectare was obtained and the energy input obtained with the following expression:

$$E_{fa} = 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (6)$$

To calculate the labour input

While

Total fertilizer input (MJ/ha)

$$= \sum_{n=1}^n \frac{N_i N_{EGV}}{AP} + \frac{P_2O_5 P_{EGV}}{AP} + \frac{K_2O K_{EGV}}{AP} \quad (7)$$

N_{EGV} = Energy equivalent value of N = 78.1MJ/kg

P_{EGV} = Energy equivalent value of P_2O_5 = 17.4MJ/kg

K_{EGV} = Energy equivalent value of K_2O = 13.7MJ/kg

N = Compound fertilizer rate applied \times percentage of N ingredient (kg)

P_2O_5 = Compound fertilizer rate applied \times percentage of P_2O_5 ingredient (kg)

K_2O = Compound fertilizer rate applied \times percentage of K_2O ingredient (kg)

n = Compound fertilizer for applied time 1th

Weed control

Pre-emergence herbicide spraying was done immediately after planting to control the weeds and a contact herbicide was also sprayed in between planting rows to control the weeds after planting in some farms. Some farmers weed their farms by cutting the weed with cutlass and hoe. For herbicide application, the energy input was obtained by measuring the amount of herbicide used and the time it took to apply the herbicide. Energy input was obtained by determining the time required and the numbers of people required for cutting using cutlass and hoe. The follow expressions were used to obtain the energy input.

When herbicide spraying was used:

$$E_{we} = H_{ber} \cdot H_{EGV} + 3.6(0.075 N T\alpha) \quad \text{MJ} \quad (8)$$

Where

Total herbicide input (MJ/ha) = $H_{ber} \cdot H_{EGV}$

H_{ber} = Applied rate (kg or lit/ha) of herbicide 1th for applied time

H_{EGV} = Energy equivalent MJ/kg or litres of herbicide

When weed is done by cutting:

$$E_{we} = 3.6(0.075 N T\alpha) \quad \text{MJ}$$

Biological energy input

The stem introduced into the soil was considered in the energy computation. The amount of stem (bundle), the amount of a stem stalk in a bundle and the weight of the stem was obtained. Biological energy input was obtained from the expression:

$$E_{bi} = \text{Amount of stem applied (kg/ha)} \times \text{Energy equivalent of stem (MJ/kg)} \quad (9)$$

Where

Energy equivalent of cassava stem = 5.6 MJ

Weight of each stalk input = 0.075 kg.

No of stalk in a bundle = 30

Complete Harvesting

Harvesting was done manually in all the farms. The time taken by the farmer to harvest the cassava root, the number of people involved, and the yields were obtained from the farms. Energy input in this operation was obtained from the expression.

$$E_{hw} = 3.6(0.075 N T_a) \text{ MJ} \quad (10)$$

$$\text{Energy use efficiency} = \frac{\text{ENERGY OUTPUT (MJ/ha)}}{\text{ENERGY INPUT (MJ/ha)}} \quad (11)$$

$$\text{Energy productivity} = \frac{\text{CASSAVA OUTPUT (kg/ha)}}{\text{ENERGY INPUT (MJ/ha)}} \quad (12)$$

$$\text{Net energy} = \text{Energy output (MJ/ha)} - \text{Energy Input (MJ/ha)} \quad (13)$$

$$\text{The energy output} = \text{yield} \times \text{energy equivalent} \quad (14)$$

Table 3. Energy Equivalent of Inputs and Outputs in Agricultural Production

Input (unit)	Energy equivalent (MJ)	References
Chemicals (kg)	120	Singh 2002
Human labour (h)	1.96	Singh, 2002
Machinery (kg)	62.71	Singh, 2002
Nitrogen (kg)	78.1	Demerirean et al., 2006
Phosphorus (kg)	17.4	Demerirean et al., 2006
Potassium (kg)	13.7	Demerirean et al., 2006
Cassava (kg)	5.6	Demerirean et al., 2006
Diesel fuel (L)	56.3	Singh, 2002

5. Results and Discussion

5.1 Result and Discussion

Energy input in the production of cassava varied from 7388.6 – 10888.66 MJ/ha as shown in Table 4. This is relatively higher than 4950 – 9130 MJ/ha obtained from cassava in Thailand (Chamsing et al., 2006). From the table, energy varied from one farm to another. The variation is caused majorly by the different amount of biological energy input, chemical energy input and difference in method of equipment acquisitions. Tractor and equipment used in the cassava production in this region were obtained through rental, private and partnership. The distance the tractor has to travel to get to the farm and the fuel used in transporting the tractor down to the farm was accounted for. The fertilizer application to the farm also varies, thus contributed to the variation.

Human labour varied from 90.56 – 421.5 MJ/ha, which was higher than 56.5MJ/ha from machinery, but lower than the input fuel of 239 – 2485.6 MJ/ha. Farm 2 was observed to have the highest energy input of 10,888.66 MJ/ha with the yield of 12,000 kg/ha, which happens to be the highest cassava yield in this study. It has been observed that low-energy inputs can lead to lower yields and conversely to higher energy demands per kg of harvested product (Woods, et al., 2010). High energy input was attributed to high amount of fuel used in transporting the tractor to the farm from the research institute and the high yield was due to high amount of fertilizer usage. Farm 10 has the lowest energy input of 6634.95 MJ/ha with a corresponding yield of 7400 kg/ha. This is as a result of low energy input in fertilizer which resulted in low yield.

The input and output energy values used in cassava production are illustrated in Table 5. The average total energy input of 8560.03 MJ/ha was required in the production of cassava. This is similar to what was obtained in Thailand from cassava (Chamsing, et al., 2006).

The pattern of energy use as shown in Fig. 1 are chemical fertilizers 64.00%, 19.50% from diesel oil and machinery, human labour 2.20% and 6.67 % of biological energy (stem). About 77.5% of the total energy inputs used in cassava production was indirect (stem, fertilizers, chemicals, machinery) and 22.5% was direct (human labour, diesel). Mean cassava yield was about 9,960.00 kg/ha. This is close to the national average yield for cassava in Nigeria which varies from 10,000 kg/ha to 15,000 kg/ha (Phillips et al., 2004).

The net energy and energy productivity value were 46,655.77 MJ/ha and 1.18 kg/MJ, respectively (Table 5). Energy use efficiency of 7.01 was obtained in this work indicates an intensive use of energy inputs in the cassava production. This was within 6.3 to 9.1 obtained by Chamsing, et al (2006) in Thailand. Higher energy ratio in Thailand is as a result of higher yield of cassava 14300 (kg/ha) as compared to 9960 (kg/ha) obtained from this study.

Table 4. Energy Input and Output in the Production of Cassava (MJ/ ha)

Item	farm 1	farm 2	farm 3	farm 4	farm 5	farm 6	farm 7	farm 8	farm 9	farm 10
Human Labour	142.7	90.56	158.25	149.25	104.62	141	330	285	421.5	176.25
Machinery	56.5	56.5	56.5	56.87	56.87	56.5	-	56.5	-	56.5
Fuel	1957.4	2485.6	2151	2103.2	2390	1764.6	239	1912	239	2045.2
Pesticide and Herbicide	1200	1200	1200	480	600	1200	480	960	600	600
Nitrogen Fertilizer	2343	4686	2343	3514.5	4686	3514.5	5857.5	3514.5	4100	857.5
Phosphorus Fertilizer	522	1044	522	783	1044	783	1305	783	913.5	1305
Potassium Fertilizer	411	822	411	615	822	615	1027.5	615.5	512.5	1027.5
Biological Energy(Cassava Stem)	756	504	567	562.50	567	693	630	441	754	567
Total Energy(MJ/ha)	7388.6	10888.66	7408.75	8264.32	10270.49	8767	9869	8567.5	7540.5	6634.95
Yield (kg/ha)	10000	12000	11300	9500	11200	8500	11500	9200	9000	7400
Energy Output(MJ/ha)	56000	67200	63280	53200	62720	47600	64400	51520	50400	41440

Table 5. Energy output – input ratio and energy forms in cassava production

Items	Unit	Quantity
Energy ratio	-	7.01
-		
Energy productivity	kg/MJ	1.18
-		
Net energy	MJ/kg	46,655.77
Direct energy	MJ/kg	1,928.61
22.5		
Indirect energy	MJ/kg	6,642.75
77.5		
Total energy input	MJ/kg	8,571.26
-		
Total energy output	MJ/kg	55,776
-		

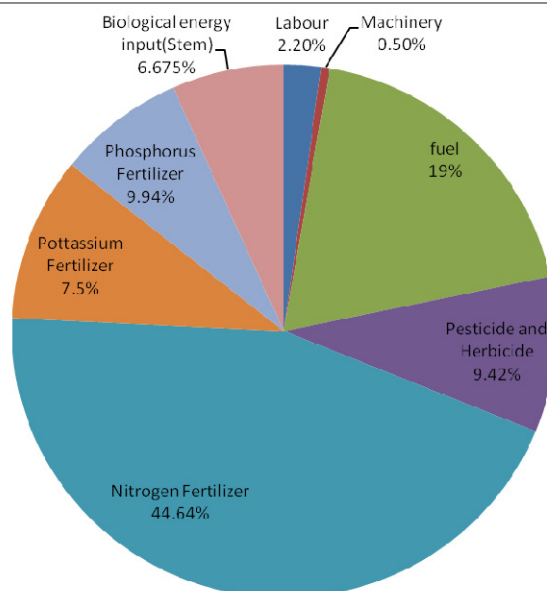


Figure 1. Pie Chat of the Energy Input in the Production of Cassava

Conclusion

The energy input in each of the cassava production stages was classified into direct and indirect energy. The indirect total energy

input used in cassava production was 77.5%, while 22.5% was direct. The average energy input in the production of cassava was 8,571.26 MJ/ha, while the average yields obtainable per hectare was 9,960.00 kg.

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