Energy life-cycle assessment and economic analysis of sweet orange production in Nigeria

C. A. Ogunlade[1*], S. O. Jekayinfa[2], J. A. Olaniran [2] and A. O. Adebayo[2]

(1. *Department of Agricultural Engineering, PMB 250, Adeleke University, Ede, Osun State, Nigeria;*
2. *Department of Agricultural Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Oyo State, Nigeria*)

Abstract: The study was undertaken to investigate the energy input and output of a group of citrus research farms in Nigeria. Data used in this study were collected in-situ on yearly basis; therefore the analysed and discussed energy values were averages of data collected over the years. The research results indicated that total energy inputs were 46.64 GJ ha^{-1}. About 35% was generated by human labour, 38% from diesel oil and machinery, while other inputs contributed 29% of the total energy input. About 87% of the total energy inputs used in sweet orange production was from direct sources (seeds, fertilizers, manure, chemicals, machinery) and 13% was from indirect sources (human labor, diesel). Mean orange yield was about 41000 kg ha^{-1}. The net energy and energy productivity value was estimated to be 31.3 GJ ha^{-1} and 0.88 kg MJ^{-1}, respectively. The ratio of energy outputs to inputs was found to be 1.67. This indicated an intensive use of inputs in sweet orange production not accompanied by increase in the final product. The gross farm income realised by the farmer is #150,000 (416.67 USD) per hectare and the gross margin computation shows a value of #116,500 (323.61 USD) per hectare; this shows that citrus production is profitable to the tune of #116,500 per hectare; The return to naira invested of 3.48 implies that for every #1 invested in citrus production, the farmer gets a profit of #3.48. Benefit–cost ratio was calculated as 2.2. A methodological shift from the use of energy from non-renewable sources to renewable ones could bring about an improvement in the energy use pattern of the research citrus farms in Nigeria.

Keywords: energy sources, energy use indices, sweet orange.

Citation: Ogunlade, C. A., S. O. Jekayinfa, J. A. Olaniran, and A. O. Adebayo. 2020. Energy life-cycle assessment and economic analysis of sweet orange production in Nigeria. Agricultural Engineering International: CIGR Journal, 22(2):123-132.

1 Introduction

Citrus (*Citrus spp*) was introduced to Nigeria by the Federal Department of Agriculture and missionaries in the 1930s (Adigun, 1992). Subsequently, it spread throughout the country and is currently rated as the most widely planted fruit tree in Nigeria. It currently features in diverse cropping systems which include the multistoried home gardens, cocoa plantations, food crop plots and a few pure stand citrus orchards (Amih, 1985; Oladokun, 1990). Due to its importance, it has received top priority research attention at the National Horticultural Research Institute of Nigeria (NIHORT) for more than two decades. The world production of citrus fruit has experienced continuous growth in the last decades of the 20th century; total annual citrus production was estimated at over 105 million tons in the period 2000-2004. Citrus constitutes the bulk of citrus fruit production, accounting for more than half of global citrus production in 2004. The rise in citrus production is

Received date: 2019-02-01 **Accepted date:** 2020-02-13

***Corresponding author: Ogunlade, Clement Adesoji,** Engr Dr, PMB 273, Ede, Osun State, Nigeria, +2348033680988, Email: clement2k5@yahoo.com;ogunlade.clement@adelekeuniversity.edu.ng

mainly due to the increase in cultivation areas and the change in consumer preferences towards more health and convenience food consumption and the rising incomes (UNCTAD, 2008). Citrus fruits are produced all around the world. According to FAO data, in 2004, 140 countries produced citrus fruits. However, most production is concentrated in certain areas. Most citrus fruits are grown in the Northern Hemisphere, accounting for around 70% of total citrus production. Main citrus fruit producing countries are Brazil, the Mediterranean countries, the United States (where citrus fruits for consumption as fresh fruit are mainly grown in California, Arizona and Texas, while most citrus juice is produced in Florida) and China. These countries represent more than two thirds of global citrus fruit production. According to the FAO (2007) the main producing and consuming countries of citrus species are indicated in Table 1.

Table 1 Main producers and consumers of citrus products in 2005 (% of world production)

Main producers of other citrus products in 2005 (%) of world production	
Lemons & Limes (%)	Mexico 14- India 13 – Argentina 11 – Brazil 8 – United States 6 – China 5 – Iran 5 – Italy 5 – Turkey 5 – Egypt 2.7 – rest of world 25.3
Other Citrus products (%)	Nigeria 49 – China 15.7 – Colombia 10.3 where the three countries Account for 75% of world production.
Grapefruit and Pomelo (%)	United States 22 – China 10.6 – South Africa 8.7 – Mexico 8.4 – Syria 6.7 – Israel 6.3 – Argentina 4.6 – Cuba 3.7 – India 3.7 – Turkey 3.6- rest of world 21.5
Main consumers of other citrus products in 2005 (%) of world consumption	
Lemons & Limes (%)	United State 14 – India 11 – Mexico 10 – Brazil 7 – China 5 – Italy 5 – Argentina 3 – Turkey 3 – Spain 2.5 – Egypt 2 – rest of world 30
Other Citruses (%)	Nigeria 44 – China 16 – Colombia 10.6 these three countries account for (70.6%) of world consumption – guinea 3 – Japan 3 –Philippine 3 – Saudi Arabia 2 – Nepal – rest of the world 16.4
Grapefruit and Pomelo (%)	United States 12 – Japan 12 – China 8.7 – France 6 – Syria 6 – Mexico 5 – Netherlands 5 – United Kingdom 3.7 – Canada 3 – South Africa 3 – India 3 – Germany 2.7 – Italy 2.3 – rest of the world 27.6

Note: Source: FAO (2007)

1.1 Energy analysis in agricultural production

Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living (Uhlin, 1998) most especially to boost food security. Continuous increase in demands of food products have resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. This does not come without any adverse effects because intensive use of energy causes problems threatening public health and environmental hazards. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system (Uhlin, 1998). Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, and indirectly in the fertilizers and chemicals produced off the farm (Fawusi and Fayemi, 1978; Kolade and Olaniyan, 1998). Energy's share of agricultural production expenses varies widely by activity, production practice, and locality. Energy life cycle analysis is usually used to evaluate the efficiency and environmental impacts of the production systems (Uhlin, 1998). Considerable studies have been conducted on energy use in agriculture (Ram et al. 1980; Dutt,1982; Pathak and Binning 1985; Farsaie and Singh, 1985; Yadav et al. 1991; Singh and Singh, 1992; Thakur and Mishra, 1993; Stephen and Jackson, 1994; Franzluebbers and Francis. 1995; Baruah and Bhattacharya, 1995; Singh et al. 1997; Uhlin, H. E. 1998; CAEEDAC 2000; Kennedy, 2000; Dincer, 2001; Singh et al. 2002; Mandal et al. 2002; Pretty et al. 2002; Gezer et al. 2003; Hacıseferogulları et al. 2003; Demirbaş, 2003; Ozkan et al. 2004a; De Jonge, 2004; Ozkan et al. 2004b; Jekayinfa and Bamgboye, 2004; Yilmaz et al. 2005; Sartori et al. 2005; Jekayinfa and Bamgboye, 2006; Demircan et al. 2006; Streimikiene et al. 2007; Jekayinfa, 2007; Jekayinfa and Olajide, 2007; Jekayinfa and Bamgboye, 2007; Uzunoz et al. 2008;

Kizilaslan, 2009; Jekayinfa et al. 2018; Fadara et al. 2019) . In recent times, the need for cost-effective energy saving technologies or practices is being recognized by many governments and manufacturing industries, hence forcing them to review their energy policies. This accounts for the extensive energy-related research work that has been done on many industrial systems with the aim of analyzing, improving the design and optimizing the performance of energy systems. Such industrial systems include, sunflower oil expression (Farsaie and Singh, 1985), palm-kernel oil processing (Jekayinfa and Bamgboye, 2004, 2007), cashew nut processing (Jekayinfa and Bamgboye, 2006), poultry processing (Jekayinfa, 2007), cassava-based foods (Jekayinfa and Olajide, 2007), rice production and processing (Jekayinfa et al., 2018), organic fertilizer production (Fadare et al., 2010), etc. The energy analysis is based on the first law of thermodynamics, which expressed the principle of the conservation of energy. It is revealed from the search of literature that there has not been any study done to determine the energy life cycle analysis and economic analysis of citrus production in Nigeria; this is required to improve the design and performance of energy-transfer system, the aim of this study therefore was to determine the total amount of input–output energy used in sweet orange production in a group of citrus research farms in Nigeria, investigate the distribution of different energies utilized during management practices, evaluate the efficiency of input energy consumption and make an economical analysis of citrus production in Nigeria.

2 Materials and methods

2.1 Citrus farm location

The study was carried out in a group of citrus research farms managed by the National Horticultural Research Institute of Nigeria (NIHORT) based in Ibadan, South Western part of Nigeria. The institute was set up by the Federal Government of Nigeria to conduct research into the genetic improvement, production, processing, storage, utilization and marketing of tropical fruits, vegetable and ornamental plants. NIHORT is located at coordinate 7.4052°N, 3.8499°E, Jericho Reservation Area, Ibadan, Oyo State, Nigeria. Data was collected for a total of 150 citrus trees under good monitoring from nursery to full growth.

2.2 Energy analysis

The amount of inputs used in the production of citrus was specified in order to calculate the energy equivalences in the study. Energy input includes human labor, machinery, diesel fuel, chemical fertilizer, pesticides and seed amounts while the output yield is the grain of citrus. Human energy expenditure was quantified by multiplying the number of persons engaged in an operation by the man-hour requirement and energy equivalent for human power. According to Jekayinfa and Bamgboye (2004, 2006, 2007), the maximum continuous energy consumption rate of 0.30 kW and conversion efficiency of 25%, the physical power output of a normal human labour in tropical climates is approximately 0.075 kW sustained for an 8-10 h workday.

Basic information on energy inputs and citrus yields were entered into SPSS 15 spreadsheets. Based on the energy equivalents of the inputs and output (Table 2), output–input energy ratio, energy productivity, specific and energy net energy gain were calculated as used by previous researchers (Ram et al. 1980; Dutt, 1982; Pathak and Binning, 1985; Farsaie and Singh, 1985; Yadav et al. 1991; Singh and Singh, 1992; Hacıseferogulları et al. 2003; Thakur and Mishra, 1993; Stephen and Jackson, 1994; Baruah and Bhattacharya, 1995; Franzluebbers and Francis, 1995; Singh et al. 1997; CAEEDAC, 2000; Kennedy, 2000; Dincer, 2001; Singh et al. 2002; Mandal et al. 2002; Pretty et al. 2002; Gezer et al. 2003; Demirbaş, 2003; De Jonge, 2004; Ozkan et al. 2004a; Ozkan et al. 2004b; Jekayinfa and Bamgboye, 2004; Yilmaz et al. 2005; Canakci et al. 2005; Sartori et al. 2005; Demircan et al. 2006; Jekayinfa and Bamgboye, 2006; Jekayinfa, 2007; Jekayinfa and Bamgboye, 2007; Jekayinfa and Olajide, 2007; Esengun et al. 2007; Erdal et al. 2007; Streimikiene et al. 2007; Shahan et al. 2008; Uzunoz et al. 2008; Kizilaslan, 2009; Jekayinfa et al. 2018; Fadara et al. 2019), as presented in Equations 1-4. The input energy was also classified into direct and indirect, renewable and non-renewable forms; the direct energy included human labor, diesel, electricity; Indirect included seeds, fertilizers, manure, chemicals, machinery; Renewable included human labor, seeds, manure and non-renewable energy included diesel, chemical, fertilizers, machinery.

The following energy use indices were estimated from the collected input and output data:

Output-input ratio=(Output energy (MJ ha^{-1}) / (Input energy (MJ ha^{-1}) (1)

Energy productivity=(Citrus output (kg ha^{-1}) / (Input energy (MJ ha^{-1}) (2)

Net energy gain= Energy outpur(MJ ha^{-1}) –Energy input (MJ ha^{-1}) (3)

$$Specific\ Energy = \frac{Input\ energy\ (\mathrm{MJ\ .ha^{-1}})}{Citrus\ output(\mathrm{kg\ .ha^{-1}})} \quad (4)$$

Indirect energy consists of seeds, fertilizers, pesticides and machinery energy while direct energy covered human labor and diesel fuel used in the citrus production. Nonrenewable energy includes diesel, pesticide, fertilizers and machinery, and renewable energy consists of human labor and seeds.

2.3 Economic analysis

Net Farm income, benefit–cost ratio, stochastic frontier production function and gross margin analysis as economic indicators were calculated based on the existing price of the inputs and outputs as detailed below:

a. Net farm income (*NTI*): this is the difference between gross income (*GI*) and total cost of production (*TCP*). It was defined as the surplus resulting from business operations which could be withdrawn without reducing the future scale of the business. Equation 5 was used for determining the Net Farm income.

$$NTI = GI - TCP \quad (5)$$

Where: *NTI* is the Net Farm Income (Naira), *GI* is the gross income or total return or total value product in Naira (defined as total output multiplied by price per unit of produce), *TCP* is the total cost of production which is a summation of total variable cost and total fixed cost (Naira

b. Benefit cost ratio and gross margin analysis: The benefit–cost ratio is simply the costs of the project divided into the anticipated returns; it is the ratio of present value of the streams of benefit to the present value of streams costs. If the projected revenue is more than the projected cost, the ratio is positive. However, the formula for the cost-benefit analysis accounts for variables such as inflation and other discounting principals. Every project has a time frame required for implementation thus the only accurate ratio is one that considers discounting variables. It was obtained from the net present value (*NPV*) as given in Equation 6:

$$NPV = \frac{V}{(1+r)^t} \quad (6)$$

Where: *NPV* is the value that will be used in the cost-benefit ratio equation (Naira). *V* is the value of the benefits (Naira), *r* is the discount rate (decimal) and *t* is the time frame (years). The *NPV* is the value used as the projected benefit value using all factors to define it in real monetary terms.

The gross margin analysis evaluates the costs and returns of an individual enterprise, it was estimated using Equation 7

$$GM = TR - TVC \quad (7)$$

Where: *GM* is the gross margin (Naira. ha^{-1}), TR is the total revenue (Naira.ha^{-1}) and *TVC* is the total variable cost

3 Results and discussion

The energy equivalent for different inputs and outputs in citrus production is presented in Figure 1.

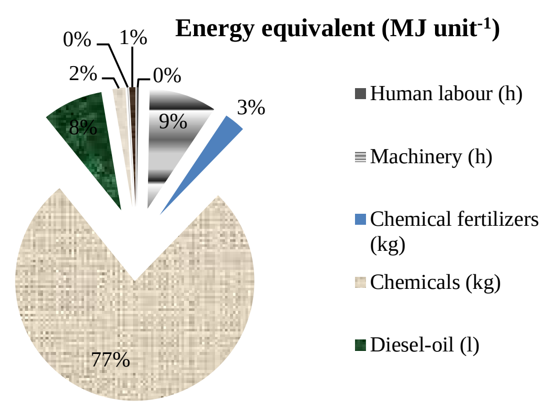

Figure 1 Energy equivalents of different input and output values used different farming system

3.1 Energy requirements and input–output relationships of citrus (sweet orange)

Two common types of tractor used for tillage operations at the research centre are the 240 Massey Ferguson brand and the FIAT brand. Tillage activities are performed mainly between March and October and the commonly used operations and equipment in citrus production were taken as the base for the research sample. The first tillage in the research region starts in March and continues till September–October. In the present study area, citrus orchards are irrigated by irrigation pumps from bore holes particularly dug for this purpose. Both chemical fertilizers and farm yard manure are used in the citrus research farms. Fertilizer, mainly, Urea, is applied in three splits in six months during the production period. Herbicides for weeding are rarely used; rather hoeing is a very common practice for weeding. The inputs used in citrus (sweet orange) production under investigation and their energy equivalents, output energy equivalent and energy ratio are illustrated in Tables 2 and 3.

Table 2 Amounts of inputs and output in citrus (sweet orange) production

Inputs	Quantity per unit area (ha)
Human Labour (h)	7610
Land preparation	50
Cultural Practices	7560
Transplanting of citrus	900
Budding of citrus with scion	3780
Weeding	900
Marking out	90
Digging of holes	135
Seed planting	180
Prunning of seedling	900
Slashing	45
Harvesting of fruits	630
Machinery(h)	11.69
Land preparation	3.17
Cultural practices	4.54
Transportation	3.98
Chemical fertilizer (kg)	60
Nitrogen	60
Phosphorus	0
Potassium	0
Manure (kg)	4000
Chemicals (kg)	3.0
Pesticides (general	1.5
Fungicides	1.5
Herbicides	0
Diesel oil (l)	300
Electricity (kW h)	620.45
Water for irrigation (m^3)	300.05
Yield (kg)	41000

Table 3 Energy consumption and energy input–output relationship for citrus (sweet orange) production in Nigeria

Input Quantity per unit area (ha)	Energy equivalent (MJ unit^{-1})	Total energy equivalent (MJ)	Percentage of total energy input (%)
Human labour		16150.40	34.63
Land preparation	1.96	98.00	0.21
Cultural practices	1.96	14817.60	31.77
Harvesting	1.96	1234.80	2.65
Machinery		732.97	1.57
Land preparation	62.70	198.76	0.43
Cultural practices	62.70	284.66	0.61
Transportation	62.70	249.55	0.54
Chemical fertilizer		3636.00	7.80
Nitrogen	60.60	3636.00	7.80
Phosphorus	11.10	0	0
Potassium	6.70	0	0
Farm yard manure	0.3	1200	2.60
Chemicals		436.50	0.90
Pesticides (general)	199	298.50	0.60
Fungicides	92	138.00	0.30
Herbicides	238	0	0
Diesel-oil	56.31	16893.00	36.22
Electricity	11.93	7401.97	15.87
Water for irrigation	0.63	189.32	0.41
Total energy input		46640.16	100
Yield	1.9	77900.00	
Energy output–input ratio		1.67	

The results revealed that 7,610 h of man power and 11.69 h of machinery power per hectare are needed to produce sweet orange in the research farm used in this study. Cultural practices, consisting transplanting, budding with scion, weeding, marking out, gigging of holes, seed planting, pruning of seedling, accounted for about 92% of the total man power, followed by harvesting (7.65%) and land preparation (0.61%). Cultural practices have the biggest proportional share (38.84%) of the total machinery power used in citrus production, followed by transportation and land preparation in that order. Only 60 kg ha^{-1} of nitrogen derived from urea fertilizer was used in the present study and this amounted to 3636 MJ ha^{-1} giving 7.80% of the total energy input. Out of all the farm operations in producing sweet orange, diesel oil consumed the most energy (36.22%), followed by human labour (34.63%), electricity (15.87%), and chemical fertilization (7.80%).

From Table 3, it is shown that farm yard manure, machinery usage, chemicals (pesticides and fungicides) application and irrigation consumed 2.60%, 1.57%, 0.90% and 0.41% of the total energy input respectively. The mean yield of citrus was 41 tonnes with a weighted mean energy ratio of 1.67 (Table 3).

3.2 Energetics of producing citrus fruits (sweet orange)

The energy input and output, yield, energy use efficiency, specific energy, energy productivity and net energy in the citrus plantation used for this study are shown in Figure 2.

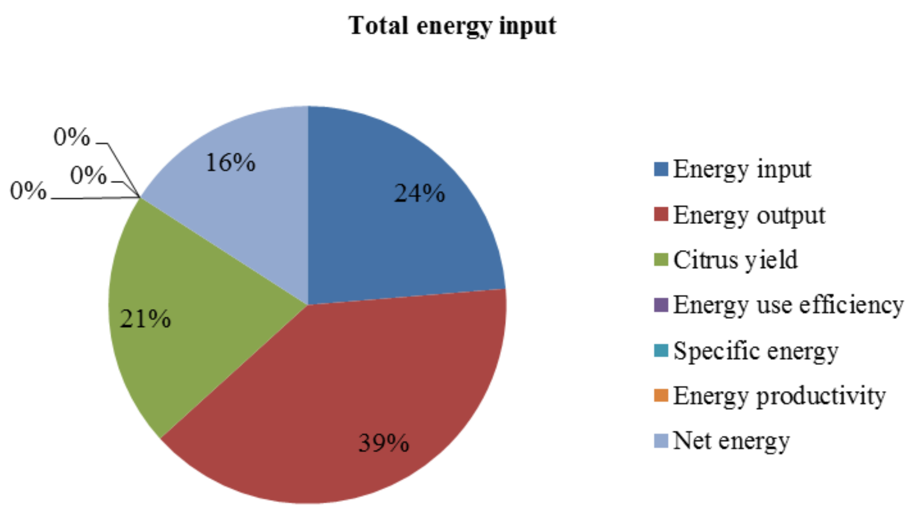

Figure 2 Energy input–output ratio in citrus (sweet orange) production

Energy use efficiency (energy ratio) was calculated as 1.67. Ozkan et al. (2004b) reported orange output/input ratio of 1.25 in Turkey. In this study, the average energy productivity of sweet orange production was 0.88; this implies that 0.88 orange output was obtained per unit energy. Calculation of energy productivity rate is well documented in the literature (Sartori et al., 2005; Esengun et al., 2007; Erdal et al., 2007; Canakci et al., 2005; Shahan et al., 2008) such as stake-tomato (1.0), cotton (0.06), sugar beet (1.53), and wheat (0.096). The specific energy and net energy of sweet orange production were 1.14 MJ kg^{-1} and 31259.84 MJ ha^{-1}, respectively. Canakci et al. (2005) reported specific energy for field crops and vegetable production in Turkey, as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for water- melon, while Shahan et al. (2008) reported specific energy of 10.43 MJ kg^{-1} for wheat production in Turkey. The distribution of total energy input as direct, indirect, renewable and non-renewable forms are shown in Figure 3.

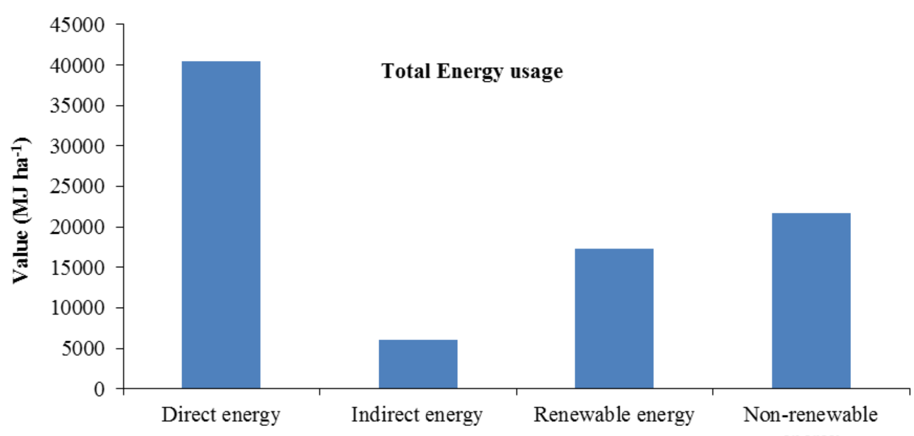

Figure 3 Total energy input in the form of direct, indirect, renewable and nonrenewable

The total energy input could be classified as direct (86.72%), indirect energy (12.88%) and renewable (37.20%) and non-renewable energy (46.52%). The implication of these results is that the energy use pattern in the investigated citrus research farms is based more on non-renewable and direct energy sources than on the renewable and indirect sources, which in other words, shows the more dependence on fossil-based energy sources like diesel and electricity. It therefore follows that citrus production in Nigeria is very sensitive to possible changes in the price of fossil fuels and their supply availability. Earlier researchers on the subject matter have observed similar energy use trends in various crop production systems (Ram et al. 1980; Dutt, 1982; Pathak and Binning, 1985; Farsaie and Singh, 1985; Yadav et al. 1991; Singh and Singh, 1992; Hacıseferogulları et al. 2003; Thakur and Mishra, 1993; Stephen and Jackson, 1994; Baruah and Bhattacharya, 1995; Franzluebbers and Francis, 1995; Singh et al. 1997; Uhlin, 1998; CAEEDAC, 2000; Kennedy, 2000; Dincer, 2001; Singh et al. 2002; Mandal et al. 2002; Pretty et al. 2002; Gezer et al. 2003; Demirbaş, 2003; De Jonge, 2004; Ozkan et al. 2004a; Ozkan et al. 2004b; Jekayinfa and Bamgboye, 2004; Yilmaz et al. 2005; Canakci et al. 2005; Sartori et al. 2005; Demircan et al. 2006; Jekayinfa and Bamgboye, 2006; Jekayinfa, 2007; Jekayinfa and Bamgboye, 2007; Jekayinfa and Olajide, 2007; Esengun et al. 2007; Erdal et al. 2007; Streimikiene et al. 2007; Shahan et al. 2008; Uzunoz et al. 2008; Kizilaslan, 2009; Jekayinfa et al. 2018)

3.3 Economic analysis of citrus fruits (sweet orange)

The result of economic analysis is summarized in Table 4.

Table 4 Economic analysis of citrus production

Variables	Unit price (Naira, #)	Value	Percentage
Variable cost			
Planting materials	50	7500	22.39
Agrochemical (litre)	500	4000	11.94
Fertilizer (kg)	100	9000	26.86
Family labour (man.hr)	-	4000	11.94
Hired labor (man.hr)	-	6000	17.9
Others	-	3000	8.97
Total		33,500 *(93.05 USD)*	100
Farm Income			
	Yield (7500 balls of citrus)		
	Average price /ball = 20 naira		
	Gross farm income	150,000 *(416.67USD)*	
	Gross margin (a-1)	116, 500 *(323.61 (USD)*	
	Return to Naira Invested (d/1)	3.48	

The gross farm income realised by the farmer is #150,000 per hectare and the gross margin computation shows a value of #116,500 per hectare; this shows that citrus production is profitable to the tune of #116,500 per hectare; The return to naira invested of 3.48 implies that for every #1 invested in citrus production, the farmer gets a profit of #3.48. The positive value indicates that the initiative is deemed worth the money invested. This value of benefit–cost ratio was compared and found to be consistent with findings reported by other authors, such as 2.53 for sweet cherry (Demircan et al., 2006), 2.37 for orange, 1.89 for lemon and 1.88 for mandarin (Ozkan et al., 2004a). The values are also in tandem with results on exotic vegetable (watermelon) in Ekiti and Borno States respectively, they obtained the gross margin for water melon in Ekiti States as #138, 044.22 (383 USD) while Ibrahim (2011) recorded a gross margin of #105,002.95 (291.67 USD) per hectare from watermelon in Borno State. The net return from sweet orange production obtained was 6710 \$ ha^{-1}. Energy management is an important issue in terms of efficient, sustainable and economic use of energy. Energy use in wheat production is not efficient and detrimental to the environment due to mainly excess input use. Therefore, reducing these inputs would provide more efficient fertilizer application and diesel. Furthermore, integrated pest control techniques should be put in practice to improve pesticide use. It can be expected that all these measurements would be useful not only for reducing negative effects to environment, human health, maintaining sustainability and decreasing production costs, but also for providing higher energy use efficiency.

4 Conclusion

In this study, energy consumption for input and output energies in sweet orange production was investigated in a group of citrus research farms in Nigeria. Data for analyses were collected on the farm as the operations were taking place on yearly basis. Average total energy consumption in sweet orange production was 46.64 GJ ha^{-1}. About 35% was generated by human labour, 38% from diesel oil and machinery, while other contributed 29% of the total energy input. The total energy input could be classified as direct energy (86.72%), indirect energy (12.88%) and renewable energy (37.20%) and non- renewable energy (46.52%). Results of the study generally indicated a fair energy use pattern which could still be improved with reduction in energy inputs from cultural practices and a methodological shift from the use of energy from non-renewable sources to renewable ones. Moreover, the economic analysis showed that the citrus production business in the study area is very viable and profitable with a ratio of 1:3.48.

References

Adigun, O. O. 1992. Citrus production in Nigeria. NIHORT Occasional Paper No 28. Ibadan, Nigeria: National Horticultural Research Institute.

Amih, C. A. 1985. Citrus production in Nigeria. In *Proceedings of the National Fruit Production Workshop*, ed. O. Oyebanji, 159 - 168 . FACU, Ibadan, Nigeria, 14-16 March.

Baruah, D. C., and P. C. Bhattacharya. 1995. Utilization pattern of human and fuel energy in tea plantation. *Journal of Agriculture and Soil Science*, 8(2): 189-192.

CAEEDAC. 2000. A descriptive analysis of energy consumption in agriculture and food sector in Canada. The Canadian Agricultural Energy End-Use Data and Analysis Centre (CAEEDAC). Available at: http://www.usask.ca/agriculture/caedac/main/tpage. html. Accessed 13 September 2017.

Canakci, M., M. Topakci, I. Akinci, and A. Ozmerzi. 2005. Energy use pattern of some field crops and vegetable production: case study for Antalya Region, Turkey. *Energy Conversion Management*, 46(4): 655-666.

De Jonge, A. M. 2004. Ecoefficiency improvement of a crop protection product: the perspective of the crop protection industry. *Crop Protection*, 23(12): 1177-1186.

Demirbaş, A. 2003. Energy and environmental issues relating to greenhouse gas emissions in Turkey. *Energy Conversion and Management*, 44(1): 203–213.

Demircan, V., K. Ekinci, H. M. Keener, D. Akbolat, and C. Ekinci. 2006. Energy and economic analysis of sweet cherry production in Turkey: a case study from Isparta province, *Energy Conversion and Management*, 47(13-14): 1761-1769.

Dincer, I. 2001. Environmental issues: I-energy utilization. *Energy Sources*, 23(1): 69-81.

Dutt, B. K. 1982. Comparative efficiency of energy use in rice production. Agricultural engineering today, Available at: https://agris.fao.org/agris-search/search.do?recordID=US201302622311 Accessed 12 September 2017.

Erdal, G., K. Esengün, H. Erdal, and O Gunduz. 2007. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. *Energy*, 32(1): 35-41.

Esengun, K., G. Erdal, O. Günduz, and H. Erdal. 2007. An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. *Renewable Energy*, 32(11): 1873-1881.

Fadara, T., Adeleke, K. M., Ogunlade, C. A., S. O. Jekayinfa and O. O. Makinde. 2019. Energy Analysis in Production and Processing of Selected Crops in Nigeria, *Adeleke University Journal of Engineering and Technology*, 2(2): 203-208.

Fadare, D. A., O. A. Bamiro, and A. O. Oni. 2010. Energy and cost analysis of organic fertilizer production in Nigeria. *Energy*, 35(1): 332-340.

FAO. Agricultural Database. Available at: http://www.fao.org. Accessed 24 June 2007.

Farsaie, A., and M. S. Singh. 1985. Energy models for sunflower oil expression. *Transactions of ASAE*, 28(1): 275–279.

Fawusi, M. O. A., and A. A. A. Fayemi. 1978. A survey of problems of citrus orchards in southwestern Nigeria. *Nigerian Journal of Science*, 12(1/2): 233-245

Franzluebbers, A. J., and C. A. Francis. 1995. Energy output–input ratio of maize and sorghum management systems in eastern Nebraska. *Agriculture, Ecosystems & Environment*, 53(3): 271-278.

Gezer, I., M. Acaroğlu, and H. Hacıseferoğulları. 2003. Use of energy and labour in apricot agriculture in Turkey. *Biomass*

Bioenergy, 24(3): 215-219.

Hacıseferogulları H, M. Acaroglu, and I. Gezer. 2003. Determination of the energy balance of the citrus plant. *Energy Sources*, 25(1): 15-22.

Ibrahim, U. W. 2011. Analysis of production efficiency and profitability of watermelon in Kaga and Kukawa local government areas of Borno State, Nigeria. An unpublished M. Sc Dissertation submitted to the Department of Agricultural Economics and rural Sociology, Ahmadu Bello University, Zaria, Nigeria

Jekayinfa, S. O. 2007. Energetic analysis of poultry processing operations. *Leonardo Journal of Sciences*, 10(1): 77-92.

Jekayinfa, S. O., and A. I. Bamgboye. 2004. Energy requirements for palm kernel oil processing operations. *Nutrition & Food Science*, 34(4): 166-173.

Jekayinfa, S. O., and A. I. Bamgboye. 2006. Estimating energy requirement in cashew (*Anacardium occidentale* L.) nut processing operations. *Energy*, 31(8-9): 1305-1320.

Jekayinfa, S. O., and A. I. Bamgboye. 2007. Development of equations for predicting energy requirements of palm-kernel oil processing operations. *Journal of Food Engineering*, 79(1): 322-329.

Jekayinfa, S. O., and J. O. Olajide. 2007. Analysis of energy usage in the production of three selected cassava-based foods in Nigeria. *Journal of Food Engineering*, 82(2): 217-226.

Jekayinfa, S. O., R. Pecenka, K. F. Jaiyeoba, C. A. Ogunlade, and O. Oni. 2018. Life cycle assessment of local rice production and processing in Nigeria. In the Proceedings 12th CIGR Section VI International Symposium, 617-633, held at International Institute of Tropical Agriculture (IITA), Ibadan between, 22-25 October.

Kennedy, S. 2000. Energy use in American agriculture. Sustainable energy term paper 2000.5 January, 2000. Available at: http://mit.edu/10.391J/www/proceedings/Agriculture_Kennedy2000.pdf/. Accessed 13 September 2017.

Kizilaslan, H. 2009. Input–output energy analysis of cherries production in Tokat Province of Turkey. *Applied Energy*, 86(7-8): 1354-1358.

Kolade, J. A., and A. A. Olaniyan. 1998. Performance of 12 sweet citrus cultivars in southwestern Nigeria. *Fruits*, 53: 175-182.

Mandal, K. G., K. P. Saha, P. K. Ghosh, K. M. Hati, and K. K. Bandyopadhyay. 2002. Bioenergy and economic analysis of soybean-based crop production systems in Central India. *Biomass and Bioenergy*, 23(5): 337-345.

Oladokun, M. O. A. 1990. Tree crop based agroforestry in Nigeria: A checklist of crops intercropped with coca. *Agroforestry Systems*, 11(3): 227-241.

Ozkan, B., A. Kurklu, and H. Akcaoz. 2004a. An input–output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. *Biomass Bioenergy*, 26(1): 89-95.

Ozkan, B., H. Akcaoz, and F. Karadeniz. 2004b. Energy requirement and economic analysis of citrus production in Turkey. *Energy Conversion and Management*, 45(11-12): 1821-1830.

Pathak, B. S., and A. S. Binning. 1985. Energy use pattern and potential for energy saving in rice–wheat cultivation. *Energy in Agriculture*, 4: 271-278.

Pretty, J. N., Ball, A. S., L. Xiaoyun, and N. H. Ravindranath. 2002. The role of sustainable agriculture and renewable-resource management in reducing greenhouse-gas emissions and increasing sinks in China and India. *Transactions of the Royal Society*, 360: 1741 – 1761.

Ram, R. A., N. K. Raghuvanski, and S. V. Arya. 1980. Study on energy cost requirements for wheat cultivation. In *ISAE XVII. Annual Convention*, 80-105. New Delhi, 6-8 February 1980.

Sartori, L., B. Basso, M. Bertocco, and G. Oliviero. 2005. Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy. *Biosystems Engineering*, 91(2): 245-256.

Shahan, S., A. Jafari, H. Mobli, S. Rafiee, and M. Karimi. 2008. Energy use and economical analysis of wheat production in Iran: A case study from Ardabil province. *Journal of Agricultural Technology*, 4(1): 77-88.

Singh, H., D. Mishra, and N. M. Nahar. 2002. Energy use pattern in production agriculture of a typical village in arid zone India—Part I. *Energy Conversion and Management*, 43(16): 2275-2286.

Singh, S., and G. Singh. 1992. Energy input crop yield relationship for four major crops of Northern India. *Ama-Agricultural Mechanization in Asia Africa and Latin America*, 23(2): 57-61.

Singh, S., S. R. Verma, and J. P. Mittal. 1997. Energy requirements for production of major crops in India. *Ama-Agricultural Mechanization in Asia Africa and Latin America*, 28(4): 13-17.

Stephen, K., and F. H. Jackson. 1994. *Citrus. Encylopedia of Agriculture Science, Vol. 4*. New York: Academic Press Inc.

Streimikiene, D., V. Klevas, and J. Bubeliene. 2007. Use of EU structural funds for sustainable energy development in new EU member states. *Renewable and Sustainable Energy Reviews*, 11(6): 1167-1187.

Thakur, C. L., and B. L. Mishra. 1993. Energy requirements and energy gaps for production of major crops in Madhya Pradesh.

Agric Situation India, 48: 665–689.

Uhlin, H. E. 1998. Why energy productivity is increasing: an I–O analysis of Swedish agriculture. *Agricultural Systems*, 56(4): 443–465.

UNCTAD. 2008. Info Comm Market information in the commodity area. United Nations Conference on Trade and Development, Palais des Nations, 8 – 14, Av. De la Paix, 1211 Geneva 10, Switzerland. Available at: http://unctad.org.en/Pages/SUC/Commodities/Commodities-Profiles.aspx. Accessed 5 January 2017

Uzunoz, M., Y. Akcay and K. Esengun. 2008. Energy input-output analysis of sunflower seed (*Helianthus annus* L.) oil in Turkey. *Energy Sources, Part B: Economics, Planning and Policy:* 3 (3): 215 – 223.

Yadav, R. N., R. K. P. Singh, and S. Prasad. 1991. An economic analysis of energy requirements in the production of potato crop in Bihar Sharif Block of Nalanda District (Bihar). *Econ. Affair*, 36(2): 112-119.

Yilmaz, I., H. Akcaoz, and B. Ozkan. 2005. An analysis of energy use and input costs for cotton production in Turkey. *Renewable Energy*, 30(2): 145–155.