

Determination of Energy Balance and Economic Analysis of Cucumber (*Cucumis Sativus*) Production in Tillage Methods

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Abstract

Energy whatever might be its source viz. human, animal, machine, electricity, solar, seed, chemical, fertilizer, gasoline or diesel has become a crucial input of agriculture right from preparatory tillage to the disposal of farm produce, energy input is necessary. This study investigates the energy balance and economic analysis of cucumber production in tillage methods. A tin of 50 g of treated cucumber seeds was planted in three different tillage systems namely; reduced, minimum and maximum tillage using foot dibbling method. Human power, machinery, diesel fuel, fertilizer, seed and pesticides were various forms of energy inputs used during the field cultivation of cucumber in the selected tillage methods. Input and output method of energy analysis was used to analyze the amount of input and output energies in each of the three tillage systems used in the production of cucumber. The calculated energy indices determined are energy ratio, energy productivity, specific energy, net energy and energy efficiency index. The result revealed that the highest total energy input and output values of 8694.09 and 8359.33 MJha⁻¹ were estimated in maximum tillage, minimum tillage has an average values of 7774.42 and 12015 MJha⁻¹, while the least average values of 5688.26 and 12736.67 MJha⁻¹ were estimated in reduced tillage, respectively. The highest benefit–cost ratio of 2.94 was found in minimum tillage, followed by maximum tillage with a value of 2.35, while least value of 2.08 was estimated in reduced tillage.

Keywords: Cucumber, tillage, energy, energy indices and net profit

DOI: 10.7176/JETP/10-1-08

Publication date: February 28th 2020

1. Introduction

Agriculture is both a producer and consumer of energy. It consumes large quantities of locally available non-commercial energy, such as seed, manure and animate energy, as well as commercial energy sources, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection chemical, irrigation water, machinery etc (Morteza *et al.*, 2012). 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 (Kizilaslan, 2009). The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery (Yadav and Khandelwal, 2013). Efficient use of these energies helps to achieve increased productivity and contributes to the economy, profitability and competitiveness of agricultural sustainability of rural communities (Omid *et al.*, 2011). Improving energy use efficiency is becoming increasingly important for combating rising energy costs, depletion of natural resources and environmental deterioration (Ashkan *et al.*, 2014).

Despite the fact that Nigeria is classified among the regions of traditional agriculture and where there is a high cost for acquiring farm machinery and equipment (Abdussalaam, 2015), many farmers still prefer replacing the conventional methods of land preparation with the use of tractor during land preparation for the production of crops. From the foregoing there are possibilities of replacement of popular conventional tillage with alternative tillage practices such as minimum and maximum tillage. The use of inappropriate tillage techniques has been found to be responsible for increased soil erosion, loss of fertility of agricultural soils, increased environmental hazards and has also contributes to unsustainability of crop production systems, as mechanized tillage requires high amount of energy input for an equal output per unit of cultivated area (Bertocco *et al.*, 2008; Yildiz, 2016). Researchers such as Ashraf (2021), Tabatabaefar *et al.* (2008) and Ashkan *et al.* (2014) investigates the effects of different tillage systems on energy consumption in the production of different crops and all of them reported that tillage is one of the major determinant factors which dictate the quantity of energy consumed during crop production. Therefore, there is need to study the energy balance and economic analyses of cucumber production in tillage methods with a view of selecting the most appropriate tillage method that will minimize the energy input and enhance the profitability of cucumber production.

2. Materials and Methods

2.1 Description of the study area

The study was carried out at the seed unit of the Oyo State Agricultural Development Programme (OYSADEP), Saki, Saki West Local Government Council Area of Oyo North Senatorial District, Oyo State, Nigeria during raining season farming from April 2018 to July, 2020. Saki is within 8° 40'3.43N latitude and 3° 23' 38.15"E longitude with an annual rainfall of about 900-1000 mm in the wet days, average of 72.7% relative humidity and temperature range of 21.8°C to 31.2°C (OYSADEP Annual Report, 2015). The community hosts a number of commercial and small farms, majorly specialized in the cultivation of food crops such as maize, guinea corn, cassava, yam, melon, cucumber to mention a few. The vegetation within the study area can be described as typical guinea savannah vegetation zone with favourable rainfall and adequate soils.

2.2 Land preparation and experimental layout

Preparation of experimental farm was carried out using manual method for reduced tillage treatment and tractor for both minimum and maximum tillage methods. The experimental farm was divided into three blocks and each block consists of three plots making a total of 9 experimental plots. The experimental farm was dimensioned 46 m x 46 m, while each block was measured 46 m x 10 m and each plot with a dimension of 10 m x 10 m with a space of 4 m in between the two adjacent plots which enabled the tractor to turn conveniently without entering the reduced tillage plots. The experimental farm was arranged in a complete randomized block design with each tillage method representing a treatment.

2.3 Source of planting material

A tin of 50 g of treated cucumber seeds was obtained from an agro vet shop at Ago-Aare in Atisbo Local Government Area of Oyo State, Nigeria and planted in three different tillage methods namely; reduced, minimum and maximum tillage using foot dibbling method as described by Abdussalaam (2015). Two to three seeds of cucumber were directly placed into the soil made with foot, slightly covered with soil and foot pressed.

2.4 Energy analysis

Identification of required operations, choosing the appropriate machinery and the right method of operation are important factors for effective analysis of energy used during the production of different crops. Operational (direct) energy consumption for the production of the cucumber, such as in land preparation, planting, fertilizer application, weeding, plant protection and harvesting were determined using input and output method of energy analysis. For converting farm inputs and outputs to energy, different energy conversion coefficients were used and these were extracted from Ashkan (2014), Fadavi *et al.* (2011), Abdussalam (2015) and Isaac and Babajide (2015). Major energy inputs that were utilized during tillage and other farming operations during field cultivation of cucumber include human energy, machinery, diesel fuel, fertilizer, seed and pesticides. The identified farming operations and equipment used in the three tillage methods are presented in Table 1.

Table 1. Farming operations and equipment used in the production of cucumber

S/N	Operations	Principle Adopted and Equipment Used		
		Reduced	Minimum	Maximum
1	Land preparation	Manual with the use of hoe and cutlass	Mechanized, 4W tractor, plough	Mechanized, 4W tractor, plough and harrow
2	Planting	Manual and knapsack sprayer	Manual and knapsack sprayer	Manual and knapsack sprayer
3	Weeding	Manual and knapsack sprayer	Manual and knapsack sprayer	Manual and knapsack sprayer
4	Fertilizer application	Manual with the use of knapsack sprayer	Manual with the use of knapsack sprayer	Manual with the use of knapsack sprayer
5	Plant protection	Manual with the use of knapsack sprayer	Manual with the use of knapsack sprayer	Manual with the use of knapsack sprayer
6	Harvesting	Manual by hand picking	Manual by hand picking	Manual by hand picking

2.4.1 Energy demand of land preparation in tillage methods

Energy demands of land preparation in reduced tillage using human power and for both minimum and maximum tillage using tractorization method are obtained by using equations 1 and 2, respectively as described by Isaac and Babajide (2015) as:

$$E_{IP} = 3.6(0.075 NTa) \quad 1$$

$$E_{tp} = 47.8D + 3.6(0.075 NTa) \quad 2$$

Where:- D = Amount of diesel consumed per unit operation (L), Ta = Useful time spent by a male worker per unit operation (hr), N = Number of persons involved in an operation

2.4.2 Planting, fertilizer application, weeding and plant protection operations

The energy demands of planting, fertilizer, weeding and plant protection operations was estimated from the addition of the equivalent energy of the physical inputs used per hectare from cucumber seed, fertilizer, pesticide and human energy expended during field planting of cucumber. The total energy consumed during planting was expressed from equations 3 and 4 as described by Ashkan (2014) and Isaac and Babajide (2015):

$$E_S = \text{Quantity used} \left(\frac{\text{kg}}{\text{ha}} \right) \times \text{energy equivalent} \quad 3$$

$$E_M = 3.6(0.075 NTa) \quad 4$$

Therefore, embodied energy demand for planting operation was expressed by equation 5 as:

$$E_P = E_S + E_M \quad 5$$

Where:- E_S = Seed energy input (Kg/ha), E_M = Human energy (MJ/ha)

It should be noted that weeding operation was carried out using both hoeing and chemical control methods.

2.4.3 Energy demand of cucumber harvest

Harvesting of cucumber fruits was done manually by picking the matured fruits with bare hand. The time taken by the workers to harvest the fruits, the number of people involved and the quantity of fruits harvested were recorded. Energy demand of harvesting operation was analyzed using the expression in equation 6 as described by Isaac and Babajide (2015):

$$E_M = 3.6(0.075 NTa) \quad 1 \quad 6$$

2.4.4 Energy indices of cucumber production

The calculated energy indices of cucumber production in tillage methods in terms of energy ratio (ER), Energy Productivity (EP), Specific Energy (SE), Net Energy (NE) and Energy efficiency index (EEN) were calculated using equations 7, 8, 9 and 10, respectively as described by Abdussalam (2015) as:

$$\text{Energy Ratio} = \frac{\text{Energy output (MJha}^{-1}\text{)}}{\text{Energy input (MJha}^{-1}\text{)}} \quad 7$$

$$\text{Energy Productivity} = \frac{\text{Crop Yield (kgha}^{-1}\text{)}}{\text{Total Energy input (MJha}^{-1}\text{)}} \quad 8$$

$$\text{Specific Energy} = \frac{\text{Energy input (MJha}^{-1}\text{)}}{\text{Crop output (MJha}^{-1}\text{)}} \quad 9$$

$$\text{Net Energy} = \frac{\text{Energy output (MJha}^{-1}\text{)}}{\text{Energy input (MJha}^{-1}\text{)}} \quad 10$$

$$\text{Energy Efficiency Index} = \frac{E_o - E_i}{E_o} \times 100 \quad 11$$

Where:- E_i = Energy input (MJ/ha), E_o = Energy output (MJ/ha)

The different forms of energy inputs used in the analysis of the cucumber production and their energy equivalent and are as presented in Table 2.

Table 2: Energy equivalents of input and output in agricultural productions

Input Source	Unit	Energy equivalent (MJ)	References
Human labour	H	1.96	Ashkan et al., 2014
Machinery	H	69.83	Morteza <i>et al.</i> , 2012
Diesel fuel	L	56.31	Morteza <i>et al.</i> , 2012
Chemical Fertilizers			
Nitrogen	Kg	78.1	Fadavi et al., 2011
Phosphorus	Kg	15.80	Yildiz, 2016
Potassium (kg)		9.28	Erdal <i>et al.</i> , 2007
Cucumber seed	Kg	0.7	Morteza <i>et al.</i> , 2012

2.5 Economic analysis and cost benefit ratio of cucumber production

The economic analysis of cucumber production in terms of total cost of production, gross and net monetary returns was analyzed using the method described by Khan *et al.* (2009).

2.5.1 Total cost of production

The total cost of production (cost C) of cucumber production was estimated by using the addition of monetary values of all energy inputs during different tillage and farming operations such as labourer, fertilizer, chemical, seed, fuel, hired machinery and tractor with implement for farming operations.

2.5.2 Gross monetary returns

Gross monetary return was estimated by multiplying the energy outputs (yields) of the crop by the market price in naira per kg (₦kg⁻¹) using equation 12 as described by Khan *et al.* (2009):

$$\text{Gross monetary Return} = \text{Yield (kg ha}^{-1}\text{)} \times \text{Market price of the yield (₦kg}^{-1}\text{)} \quad 12$$

2.5.3 Net monetary returns

The net economic return of cucumber production was calculated as gross return minus the total cost of production (Khan *et al.*, 2009) by equation 13:

$$\text{Net monetary return} = \text{Gross monetary return (₦ha}^{-1}\text{)} - \text{Total production cost (₦ha}^{-1}\text{)} \quad 13$$

2.5.4 Cost benefit ratio

The cost benefit ratio was calculated using the expression described by Majid (2011) in equation 14 as:

$$\text{Cost benefit ratio} = \frac{\text{Gross monetary return}}{\text{Total cost of production}} \quad 14$$

3. Results and Discussions

3.1 Analysis of input–output energy use in cucumber production in tillage methods

The physical inputs used in cucumber production and their energy equivalents together with the energy equivalent of the yield are shown in Table 3. It is observed from the table that reduced tillage has the highest physical human power input which varied from 330.44 – 350.0 h with an average of 333.48 h, followed by maximum tillage with a range of 149.0 – 189.0 h and an average value of 148.4 h, while the least human power input ranges from 114.13 – 175.0 h with an average of 144.56 h was used in minimum tillage. The highest machinery physical input was recorded in maximum tillage which varied from 14.64 – 16.5 h with an average value of 15.30 h, minimum tillage has a range of 11.4 – 11.6 h with average value of 11.2 h, while the least machinery input range of 5.8 – 6.5 h with an average of 5.9 h was observed in reduced tillage. The same amount of fertilizer, seed and pesticide inputs of 29.42 kg, 6.4 kg and 6.25 liters, respectively were used on yearly basis for the production of cucumber for the three tillage methods treated. The highest total energy input between the ranges of 8196.54 and 9525.61 MJha⁻¹ was estimated in maximum tillage, minimum tillage has a range of 7474.37 and 8297.54 MJha⁻¹, while the least range of 5677.65 and 5764.87 MJha⁻¹ of total energy was estimated in reduced tillage for the three cropping seasons. Morteza *et al.*, (2012) reported similar result with total human hourly input of 45.98 hha⁻¹, 18.85 hha⁻¹ of machinery input and total energy input of 39,232.79 MJha⁻¹ in the production of corn grain, while Ashraf *et al.* (2021) reported labor input, machinery input, total Energy input respectively of 59.50 hha⁻¹, 26.25 hha⁻¹, 21360.0 MJha⁻¹ and 242.70 hha⁻¹, 80.05 hha⁻¹, 44370.0 MJha⁻¹ for wheat and rice productions respectively.

The highest cucumber yield range of 12345 and 12990 kgha⁻¹ with an average yield value of 12736.7 kgha⁻¹ was harvested in maximum tillage plots, followed by minimum tillage which ranges between 12120 and 12670 kgha⁻¹ with an average yield of 12415.33 kgha⁻¹, while the least harvested yield range of 8620 and 9760 kgha⁻¹ was harvested in reduced tillage. This result is similar to the findings of Morteza *et al.* (2012) who reported an average

yield of 12250 kg ha^{-1} and total energy output of 96359.10 MJ ha^{-1} for corn grain production. Similarly grain yield and energy output of 4325.38 kg ha^{-1} and 121500.0 MJ ha^{-1} in wheat and 4441.24kg ha^{-1} and 75500 MJ ha^{-1} in rice productions, respectively were reported by Ashraf et al. (2021).

The anthropogenic energy input ratios of cucumber production in the three tillage methods, namely; reduced, minimum and maximum is presented in Figure 1. It is noticed from the figure that the highest average human energy input of 653.62 MJ ha^{-1} was used in reduced tillage, followed by maximum tillage with a value of 333.98 MJ ha^{-1} , while the least human energy input of 290.82 MJ ha^{-1} was recorded in minimum tillage. Maximum tillage has the highest average machinery energy input of 1069.10 MJ ha^{-1} , followed by minimum tillage with an average value of 782.10 MJ ha^{-1} , while the least average machinery input of 409.90 MJ ha^{-1} was obtained in reduced tillage. The highest diesel fuel energy input with an average value of 2664.68 MJ ha^{-1} was estimated in maximum tillage, followed by minimum tillage with an average value of 2076.34 MJ ha^{-1} , while zero value of diesel fuel energy input was consumed in reduced tillage. Figure 1 further revealed that the same quantity of fertilizer, seed and pesticides inputs with average values of 2123.54, 7.60 and 24945 MJ ha^{-1} , respectively were used on yearly basis in the three tillage methods.

TABLE 3: Physical energy input used in the production of cucumber

Item	Quantity used in Tillage Methods (ha)			Energy Equiv.	Total Energy Equivalent (MJ/ha)		
	Reduced	Minimum	Maximum		Reduced	Minimum	Maximum
2018							
Human power, h	350	175	189	1.96	686	343	370.44
Machinery, h	6.5	11.4	16.5	69.83	453.90	796.06	1152.20
Diesel Fuel, L	00	45	60	56.3	00	2533.5	3378
Fertilizer, kg	29.42	29.42	29.42	72.18	2123.37	2123.37	2123.37
Seed, kg	6.4	6.4	6.4	1.70	7.60	7.60	7.60
Pesticide, L	7.35	7.35	7.35	339.20	2494	2494	2494
Total energy input (MJ/ha)					5764.87	8297.54	9525.61
Yield (kg/ha)					9760	12670	12990
Total energy output (MJ/ha)					7808	10136	10392
2019							
Human power, h	320	156	173.01	1.96	627.20	305.76	339.09
Machinery, h	5.3	10.6	14.78	69.83	370.10	740.20	1032.09
Diesel Fuel, L	00	33.40	42	56.3	00	1880.42	2364.6
Fertilizer, kg	29.42	29.42	29.42	72.18	2123.37	2123.37	2123.37
Seed, kg	6.4	6.4	6.4	1.70	7.60	7.60	7.60
Pesticide, L	7.35	7.35	7.35	339.20	2494	2494	2494
Total energy input (MJ/ha)					5622.27	7594.35	8360.75
Yield (kg/ha)					8650	12120	12345
Total energy output (MJ/ha)					6920	9696	9876
2020							
Human power, h	330.44	114.13	149.18	1.96	647.67	223.69	292.40
Machinery, h	5.8	11.6	14.64	69.83	405.01	810.03	1022.10
Diesel Fuel, L	00	32.25	40	56.3	00	1815.68	2257.07
Fertilizer, kg	29.42	29.42	29.42	72.18	2123.37	2123.37	2123.37
Seed, kg	6.4	6.4	6.4	1.70	7.60	7.60	7.60
Pesticide, L	7.35	7.35	7.35	339.20	2494	2494	2494
Total energy input (MJ/ha)					5677.65	7474.37	8196.54
Yield (kg/ha)					8620	12456	12875
Total energy output (MJ/ha)					6898	9964	10300

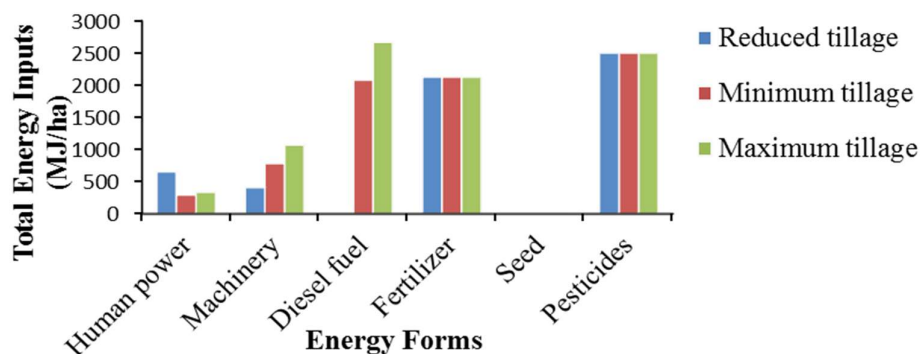


Figure 1: Anthropogenic energy input ratios of cucumber production in tillage methods

The percentage of total energy consumptions by operations in tillage methods are presented in Figures 2, 3 and 4. It can be seen from Figure 2 that for reduced tillage, plant protection has the highest percentage of energy expenditure with 45 %, followed by fertilizer application with a value of 35 %, land preparation has a percentage value of 15 %, planting has a share of 2 % of total energy expended, while the lowest percentage value of 1 % was recorded for weeding and staking operations.

Similarly, Figure 3 presents the percentage composition of energy consumed by the operations in minimum tillage during the production of cucumber and it is revealed from the figure that the highest percentage energy composition value of 37 % was recorded during land preparation, crop protection has a percentage value of 34 %, fertilizer application accounted for 25 % of total energy consumed, while planting, weeding, staking and harvesting recorded the least equal percentage energy value of 1 %.

The percentage composition of energy consumed by operations during the production of cucumber in maximum tillage is presented in Figure 4. It can be seen from the figure that the highest percentage energy value of 43 % was recorded during land preparation, followed by plant protection with percentage energy value of 30 %, fertilizer application has a percentage value of 23 %, while the least energy percentage composition of 1 % was calculated for planting, weeding, staking and harvesting operations. This result is similar to the findings of Abdussalam (2015) who reported energy consumption composition of 58 % for land preparation, 36 % for ridging, 3 % for weeding operation, 2 % for application of fertilizer and 1 % for planting in the production of maize. Ashraf et al., 2021 reported energy inputs composition of 28.96 % for chemical fertilizers, 6.31 % for rice seed energy, 44.61 % of diesel fuel energy, 10.14 % for electricity, 1.85 % for machinery, 5.32 % for pesticides energy and 2.82 % for human labour energy respectively.

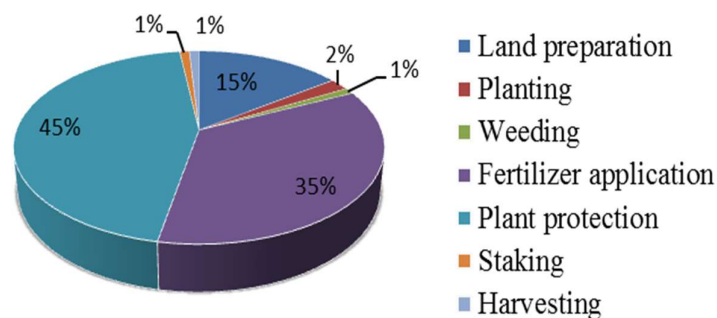


Figure 2: Composition of Energy Consumed by Operations in Reduced Tillage

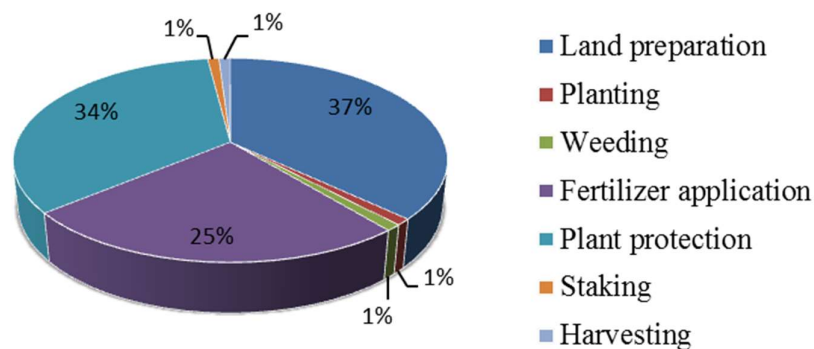


Figure 3: Composition of Energy Consumed by Operations in Minimum Tillage

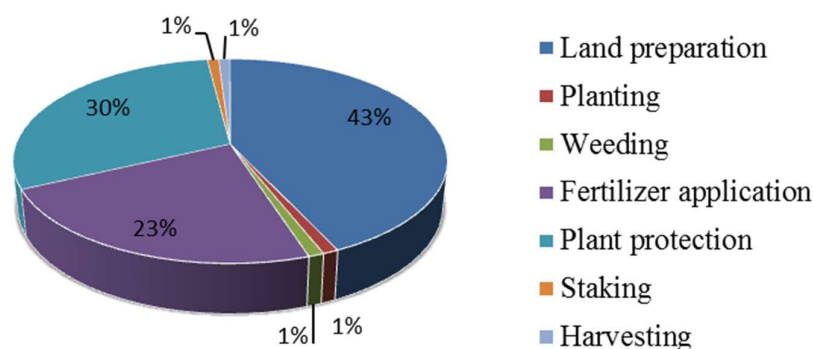


Figure 4: Composition of Energy Consumed by Operations in Maximum Tillage

3.2 Energy indices in cucumber production in tillage methods

The calculated energy ratio (energy use efficiency), energy productivity, specific energy, net energy gain and percentage energy index of cucumber production in the three tillage methods in the three cropping seasons is presented in Table 4. It can be seen from the table that minimum tillage has the highest energy ratio between the range of 1.22 and 1.67 with an average value of 1.39, followed by maximum tillage between the range of 1.25 and 1.48 with an average of 1.27, while the least energy ratio between the range of 1.21 and 1.35 with average value of 1.26 was calculated in reduced tillage. The highest energy productivity within the range of 1.53 and 1.67 MJkg^{-1} with an average of 1.6 MJkg^{-1} was observed in minimum tillage, reduced tillage has a range of 1.52 MJkg^{-1} and 1.69 MJkg^{-1} with average value of 1.58 MJkg^{-1} , while maximum tillage has the lowest energy productivity range of 1.18 and 1.36 MJkg^{-1} with an average of 1.47 MJkg^{-1} . Maximum tillage recorded the highest specific energy with a range of 0.64 and 0.73 MJha^{-1} with average value of 0.68 MJha^{-1} , followed by reduced tillage between the range of 0.59 and 0.66 MJha^{-1} with average of 0.63 MJha^{-1} , while the least specific energy between the values of 0.60 and 0.65 MJha^{-1} with average of 0.62 MJha^{-1} is observed in minimum tillage. The highest net energy gain between the ranges of 1838.46 and 2490.43 MJha^{-1} with average value of 2157.84 MJha^{-1} was estimated in minimum tillage, reduced tillage has a range of 1220.35 and 2043.13 MJha^{-1} with an average value of 1520.40 MJha^{-1} , while maximum tillage has the least energy gain between the range of 610.11 and 2103.46 MJha^{-1} with an average of 1409.60 MJha^{-1} . The highest percentage energy index between the range of 0.18 and 0.25% with an average value of 0.22% was estimated in minimum tillage, followed by reduced tillage with a range of 0.18 and 0.26% with an average of 0.21%, while the least percentage energy index between a range of 0.06 and 0.20% with an average value of 0.14 was estimated in maximum tillage. Pishgar Komleh *et al.* (2011) in their studied reported energy efficiency, energy productivity, specific energy and net energy of 2.27, 0.28 kgMJ^{-1} , 3.76 MJ kg^{-1} and 79452 MJ ha^{-1} , respectively for corn silage production, while Morteza *et al.* (2012) reported corresponding values 2.6, 0.18 kgMJ^{-1} , 5.66 MJkg^{-1} and 59,248.58 MJha^{-1} for corn grain production

3.3 Economic analysis and cost benefit ratio in cucumber production

The calculated economic analysis in cucumber production in terms of total cost of production, gross and net monetary returns and cost benefit ratio in three tillage methods is presented in Table 5. It is observed from the table that maximum tillage has the highest total cost of production with the sum of ₦276,000.00 k, followed by

reduced tillage with a total sum of ₦234,750.00k, while the least sum of ₦215,000.00k was estimated in minimum tillage. The highest gross monetary return with the sum of ₦649,500.00k was realized in maximum tillage, minimum tillage has a total sum of ₦633,500.00k and the least gross monetary return with a total sum of ₦488,000.00k was realized in reduced tillage.

The highest sum of ₦418,500.00k net monetary returns was calculated in reduced tillage, followed by maximum tillage with a sum of ₦373,500.00k, while the least sum of ₦253,250.00k was realized in reduced tillage. Minimum tillage has the highest cost benefit ratio of 2.94, followed by maximum tillage with a value of 2.35 and the least value of 2.08 cost benefit value was observed in reduced tillage. This result is similar to the findings of Morteza *et al.* (2012) who reported cost benefit ratios of 1.75 for corn grain production, respectively.

Table 4: Energy indices in cucumber production in tillage methods

Year	Items	Units	Quantity		
			Reduced	Minimum	Maximum
2018	Total energy input	MJha ⁻¹	5764.87	8297.54	9525.09
	Yield	Kg/ha	9760	12670	12990
	Total energy output	MJha ⁻¹	7808.00	10136	10392
	Energy use efficiency		1.35	1.22	1.09
	Energy productivity	MJkg ⁻¹	1.69	1.53	1.36
	Specific energy	MJha ⁻¹	0.59	0.65	0.73
	Net energy gain	MJha ⁻¹	2043.13	1838.46	610.11
	% energy index		0.26	0.18	0.06
2019	Total energy input	MJha ⁻¹	5622.27	7551.35	8360.75
	Yield	Kg/ha	8650	12120	12345
	Total energy output	MJha ⁻¹	6920.00	10832.00	11984.00
	Energy use efficiency		1.23	1.28	1.18
	Energy productivity	MJkg ⁻¹	1.54	1.60	1.48
	Specific energy	MJha ⁻¹	0.65	0.62	0.68
	Net energy gain	MJha ⁻¹	1297.73	2144.64	1515.25
	% energy index		0.19	0.22	0.15
2020	Total energy input	MJha ⁻¹	5677.65	7474.37	8196.54
	Yield	kg/ha	8620	12543	12875
	Total energy output	MJha ⁻¹	6898	9964.8	10300
	Energy use efficiency		1.21	1.67	1.25
	Energy productivity	MJkg ⁻¹	1.52	1.67	1.57
	Specific energy	MJha ⁻¹	0.66	0.60	0.64
	Net energy gain	MJha ⁻¹	1220.35	2490.43	2103.46
	% energy index		0.18	0.25	0.20

Table 5: Economic analysis and benefit-cost ratio of cucumber

Cost and return Components	Unit	Reduced	Minimum	Maximum
Yield	kg/ha ⁻¹	9760.00	12670.00	12990.00
Sale price	₦kg ⁻¹	50.00	50.00	50.00
Total cost of production	₦ha ⁻¹	234750.00	215000.00	276000.00

4. Conclusions

In this study, determination of energy balance and economic analysis of cucumber production in three tillage methods have been investigated and the following points were drawn from the study:

The results shows that the maximum tillage consumed the highest total energy of 26,082.35 MJha⁻¹ with an average value of 8,694.12 MJha⁻¹, followed by minimum tillage with a total energy value of 23,323.26 MJha⁻¹ with an average of 7,774.42 MJha⁻¹, while the least total energy value of 17,064.79 MJha⁻¹ with an average value of 5,688.26 MJha⁻¹ was expended in reduced tillage.

Averagely, minimum tillage has the highest energy ratio of 1.27 while the least value of 1.26 was estimated in reduced tillage; reduced tillage has energy productivity value of 1.57 MJkg⁻¹, while the least energy productivity

of 1.47 MJha⁻¹ was estimated in maximum tillage. The highest net energy gain of 2157.84 MJ/ha⁻¹ was analyzed in minimum tillage, followed by reduced tillage with a value of 1520.40 MJha⁻¹, while the least energy gain with a value of 1409.60 MJha⁻¹ was calculated in maximum tillage.

The highest benefit–cost ratio of 2.94 was found in minimum tillage, followed by maximum tillage with a value of 2.35, while least value of 2.08 was estimated in reduced tillage.

The highest mean net return of ₦418,500.00k was realized in minimum tillage, followed by maximum tillage with a sum of ₦373,500.00k, while the least sum of ₦253,250.00k was estimated in reduced tillage respectively.

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