Greener Journal of Agricultural Sciences
ISSN: 2276-7770; ICV: 6.15
Vol. 5 (4), pp. 122-131, July 2015

http://gjournals.org/GJAS

Research Article (DOI http://doi.org/10.15580/GJAS.2015.4.122912349)

Energy Utilization and Conservation Approach in Cashew Nut Mill

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ARTICLE INFO

Article No.: *122912349*
DOI: *10.15580/GJAS.2015.4.122912349*

Submitted: *29/12/2013*
Accepted: *20/01/2014*
Published: *14/07/2015*

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Keywords:
cashew nut, processing, energy intensity, energy wastage, energy savings

ABSTRACT

Food processing industries relies on energy to carry out the desired operations and to obtain high processing efficiencies in conversion processes that create new forms of foods. This research work was carried out using OLAM Nigeria Limited in Oyo state, Nigeria as a case study, to examine different unit operations and various patterns of energy consumption in cashew nut processing. The relationship between the energy consumption and production capacity was analyzed to compute installed capacity (P), production (Pr), percentage production capacity utilization (PPCU), energy (En) and energy intensity (EI), using standard equations. Energy wastage was identified and technical measures for improving energy efficiency were suggested. The result obtained from analysis showed that installed capacity and production were 12 million and 6 million per annum respectively. While the percentage production capacity utilization, energy intensity, energy utilized from electricity, thermal energy from either diesel or cashew nut shells (CNS), manual energy supplied by male and female were 50%, 2.08MJ, 3.10MJ (0.15%), 418.36MJ (20.12%), 573.79MJ (27.59%), 74.85MJ (3.59%), and 1009.84MJ (48.56%), respectively. The different between the total energy utilized from comparative analysis before and after conserved energy were 150,155.32MJ and 2,079.67MJ respectively. It was recommended that the locally fabricated brick mud heating mantle with an enclosed chamber over a suitable grate with a proper opening for primary and secondary channel to generate maximum heat transferred to the steam boiler and the trays for drying kernels should be work on to reduce heat loss and conserved energy.

INTRODUCTION

Energy is the lifeblood of economics around the world and global economic growth depends on adequate, reliable and affordable supplies of energy (Chineke, Nwafor, and Okoro, 2010). Industrialized agriculture and food processing industries relies on energy to carry out the desired operations and obtain high processing efficiencies in mechanization of crop handling and conveyance and thermal processing, to assure safe storage of agricultural products and conversion processes that create new forms of foods. (Jekayinfa and Bamigboye, 2006).

In recent years, energy analysis has been expanded to encompass not only the actual manufacturing process but also ancillary operations which individually consume only small qualities of energy; however they can be responsible for large total energy consumption because of the large number of such operations that are frequently needed in a production complex. A number of reasons can be put forward to emphasize the need for efficient and rational use of industrial energy. Inefficient industrial energy use could lead to huge economic losses, and excessive energy consumption adds to the costs of goods produced especially in the energy intensive industries like cashew nut processing operations.

The wide variations in energy intensity of cashew mills reveal the scope for energy conservation to be in the order of 30-48% (Atul Mohod *et al*., 2010). A number of studies have been reported in literature on the determination of energy content of unit operations. These include a study reported by Chang, Chang and Kim, 1996 involving the development of an energy model and a computer simulation models to assess the requirements of electricity, fuel and labour for rice handling, drying, storage and milling process in rice processing complex (RPC) in Korea. Other similar works reported in literature relating to evaluation of energy efficiency on processing in Nigeria (Jekayinfa and Bamigboye, 2003, 2006); Energy utilization in rural industries in Karnataka (Ramachandra 1998); Palm-Kernel oil processing in Nigeria (Jekayinfa and Bamigboye, 2007).

The Objective of the study is to identifying the patterns, and types of energy use in cashew nut processing, to determine energy use pattern, energy loss sources and excess energy use points, to identify and suggest technical measures for improving energy efficiency.

MATERIAL AND METHODS

Processing factory

The cashew nut processing industry used for study is OLAM Nig. Ltd, Oyo State, Nigeria. This company had its headquarter in Oyo town and branches in about 5 Local Governments where part of processing that involved more female workers are carried out. The major factory is situated in Iseyin and Oyo town. The study covered the unit operations performed, pattern of energy consumption and technologies in use for Cashew nut processing. The energy consumption and production of mills was analyzed to compute the disparities in energy consumption to produce the same quantity of similar product in term of Installed Capacity (P), Production (Pr), Percent Production Capacity Utilization (PPCU), Energy (En) and Energy Intensity (EI) as follows (Ramachandra, 1998).

For consistency, the energy components are calculated on the basis of 1000kg of raw Cashew nut and energy component from each source was estimated; using the following procedure.

Installed Capacity (P)

The installed capacity of the mill was determined by considering the capacity of the steam cooker, number of batches performed per day and the average working days in a year.

P (kg) = Steam Cooker Capacity X No. of batches/day X Average working days ……………….. 1

Production (Pr)

The production of the mill was determined by the average actual raw material processed on kg per year basis. The average of last three year production data was considered for the production figures.

Total Energy Utilization

The percent production capacity utilization of the mill was calculated as the ratio of actual production to the total installed capacity of the mill.

Percent production capacity utilization (PPCU) % = Pr/P x 100. …………2

Total Energy (En)

The electrical energy consumption for unit operations and lighting in the mill was estimated by direct interview method and verified from the available electrical bills on yearly basis. The quantity of biomass fuel consumed and type of biomass for processing of raw material in a year was collected by direct interview method.

All the form of energy sources were converted into the common unit of energy i.e. MJ/Year.

Evaluation of electrical energy

The rated power of each motor was multiplied by the corresponding hours of operation and summed to find the electrical energy usage by equipment. A motor efficiency of 80% was assumed to compute the electrical inputs (Johnson, 1999).

Mathematically

$$E_p = KPt \quad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where: Ep =electrical energy consumed KWh, P = rated power of motor, T = hours of operation, h;

K = power factor (assumed to be 0.8).

Using this procedure, monthly electrical bills for each mill were reconstructed within a 10% error (Johnson, 1999).

Evaluation of thermal energy

Energy from fossil fuel was assigned to each unit operation according to their consumed from fossil fuel was converted to common energy unit (J) by multiplying the quantity of fuel consumed by the corresponding calorific Value (lower heating value) of the fuel used (Ezeike 1981; Johnson, 1999; Rajput, 2001).

Mathematically,

E_F = CfW………………..4

Where : E_F = thermal energy consumed, J; C_F = Calorific Value of fuel used, J/1

W = quantity of fuel used.

Evaluation of manual energy

Manual energy was estimated based on the value recommended by (Odigboh, 1998). According to Odigboh, 1998; at the maximum continuous energy consumption rate of 0.30KW and conversion efficiency of 25%, the physical power output of a normal human labour in tropical climates is approximately 0.68MJ/h for woman and 0.75MJ/h for man sustained for an 8-10h workday. All other factors affecting manual energy expenditure were found insignificant and therefore neglected. To determine the manual energy input for a given operation, the time spent by the worker on each operation, the time spent by the worker on each operation (from cashew nut cleaning to cashew nut packing) was recorded. This included the intermittent resting periods. For any unit operation, the manual energy expenditure En was determined by

En = 0.685NTa (MJ) ……for woman…….. 5a

En = 0.75NTa (MJ) .... for man …………5b

Where: 0.075 = the average power of a normal human labour in KW;

N = number of persons involved in an operation; Ta = useful time spent to accomplish a given task (Operation) in hour.

To access the energy demands (electrical, fuel or manual) in all the 9 (nine) Units operation of cashew nut production, quantitative data on operation condition (as contained in Equation were measured).

Specific Energy Consumption (SEC): SEC can be identified as the ratio of Energy Consumption to Production. Thus:

SEC = En/Pr

Energy Intensity (EI)

EI is the ratio of Energy Consumption and Production in "per unit" terms. EI would be helpful in industries where the end products of an industry are cash products.

EI = En/ Pr (kg/kg) or (kWh/kg) ……………….6

The intra and inter variation in SEC and EI among the industries producing similar products reveals the extent of inefficient/ efficient energy consumption. The higher the variation in the value of SEC and EI for the same amount of Production among industries producing similar product reveals the extent of disparity in energy consumption.

Finally, the major issues regarding the operation were of two fold;

1. To consider cashew nut shell and its equivalent cost to fuelwood
2. To modify defined unit operations to reduced energy loses to conserve energy and cashew nut processing industries.

TABLE 1: Unit Operations and Type of Energy for Cashew Nut Processing Mill

Unit Operation	Quantity (kg)	Time (h)	Type of energy used					
			Electrical (MJ)	Thermal (MJ)		Manual (MJ)		Solar (MJ)
				Diesel	CNS	Male	Female	
Drying Raw Cashew Nut	24,000	12	----	----	----	+	+	+
Sorting/ Cleaning	24,000	6	+	----	----	+	+	----
Steaming	24,000	3.13	----	----	+	+	----	----
Cutting or Shelling/ Separation	5,600	12	----	-----	-----	+	+	----
Drying Cashew Kernel	9,634	6	----	-----	+	+	+	----
Peeling/ Grading	440	12	----	-----	----	+	+	----
Drying Grading Cashew Kernel	25,000	24	----	+	----	+	+	----
Roasting/ Separation Or grading (22.68kg per carton)	4,536	12	-----	+	----	+	+	----
Peeling/ Separation Or Grading	4,536	12	-----	+	----	+	+	----
Packaging	4,536	12	-----	+	----	+	+	----

Table 2: Unit Operations and Manual Energy Used for the Processing

Unit Operation	Manual energy (number of worker for each unit operation) Male	Female
Drying Raw Cashew Nut	5	10
Sorting / Cleaning	5	---
Steaming	6	---
Cutting or Shelling/Separation	2	78
Drying/Cashew Kernel	13	---
Roasting	2	---
Peeling/Separation or Grading	4	100
Packaging	13	---

RESULTS AND DISCUSSION

Data on the Factory

The Installed capacity of the mill was calculated to be 12,000,000kg, production 6,000,000kg and the percent production capacity utilization (PPCU) 50% was generally similar to the earlier studies conducted by Atul Mohol et al., (2010). Analysis of data on total energy consumption by the cashew nut mill provides useful information on the energy sources available to them. As indicated in the Table 3 the cashew nut mill consumed electricity, thermal (fuel) in form of diesel and Cashew Nut Shells (CNS), manual energy (male and female) and solar energy even though the energy obtained from the sun cannot be ascertain that all are useful for processing and are not considered with the total energy utilized. Table 3 with unit operations and total energy used for processing

1000kg of raw cashew nut reveals that cashew nut processing involves ten readily defined unit operations. Some of these operations are energy-intensive, and as indication of the importance of energy utilization in the overall production system is exemplified by the time and energy-use data. The unit operations with energy intensive as shown from the table 3 were steaming and peeling/grading operations. Figure 1 shows the percentage between the energy consumption as electricity 3.10MJ (0.15%), diesel 418.36MJ (20.12%), CNS 573.79MJ (27.59%), male 74.58MJ (3.59%) and female 1009.84MJ (48.56%) inform of bar and pie charts. As shown above the energy from electricity and diesel needed for direct processing unit are not high but high amount of money are spent that affect the total cost of production by which electrical energy is wasted in the food industry are shown in table 4 reported by Aderemi et al, (2009). Table 4 gave comparative analysis of energy utilization of electricity, thermal energy either diesel, CNC, or fuelwood and manual energy supplied by male and female before and after conserved energy. Figure 2 shows graphically representation needs for energy to be conserved to give better result.

Relationship between energy intensity (EI) and production (Pr)

The relationship between energy intensity (EI) and production (Pr) obtained is 2.08MJ/Kg excluding energy obtained from sun's showed the similar trends with the published result of earlier studies reported by Atul Mohod et al, (2010); Ramanchandra, (1998) and Ramachandra and Subramanian, (1987).

Relationship between energy intensity (EI) and percent production capacity utilization

The energy intensity and percent production capacity utilization were 2.08 MJ/kg and 50% respectively which when compared with result published by Atul. Mohod et al., (2010) gives considerable scope for saving of energy with better utilization of installed production capacity in the tune of 25.84%. The average percent plant capacity utilization of small scale cashew nut processing mills was found to be 55% with average energy intensity of 2.74 MJ/kg. This revealed the overall scope for saving 21.53% energy in the mill with better utilization of installed capacity. This again may be inferred, as the energy efficiency improves with better efficiency utilization of the installed production capacity.

unit operation	Quantity (kg)	Time (h)	Types of Energy Used						Total	Average	Percentage
			Electricity (MJ)	Thermal		Manual		Solar (MJ)			
				Diesel (MJ)	CNS (MJ)	Male (MJ)	Female (MJ)				
Drying Raw Cashew nut	1,000	12				45	81.6	4.85E9	126.6	05.0563	5.63
Sorting/ Cleaning	1,000	0.25	2.04			0.93			2.97	0.0013	0.13
Steaming	1,000	0.13	1.06		338.51	0.59			340.16	0.1512	15.12
Cutting or Shelling/ Separation	1,000	2.14				3.21	113.51		116.72	0.0723	7.23
Drying Cashew Kernel	279	0.17			235.28	0.77	0.58		236.63	0.1052	10.52
Peeling/ Grading	279	7.61				11.42	765.87		777.29	0.3455	34.55
Drying Graded Cashew Kernel	270	0.26		87.25		2.54			89.79	0.0399	3.99
Roasting	270	0.71		216.95		1.07			218.02	0.0969	9.69
Peeling/Separation or Grading	270	0.71				2.13	48.28		50.41	0.0224	2.24
Packaging	270	0.71		238.04		6.92			244.96	0.1090	10.90
Total			**3.10**	**542.24**	**573.79**	**74.58**	**1009.84**		**2249.55**		**100**
Average			0.001	0.241	0.2551	0.03315	0.4489				
PERCENTAGE			0.1	24.10	25.51	3.32	44.89				

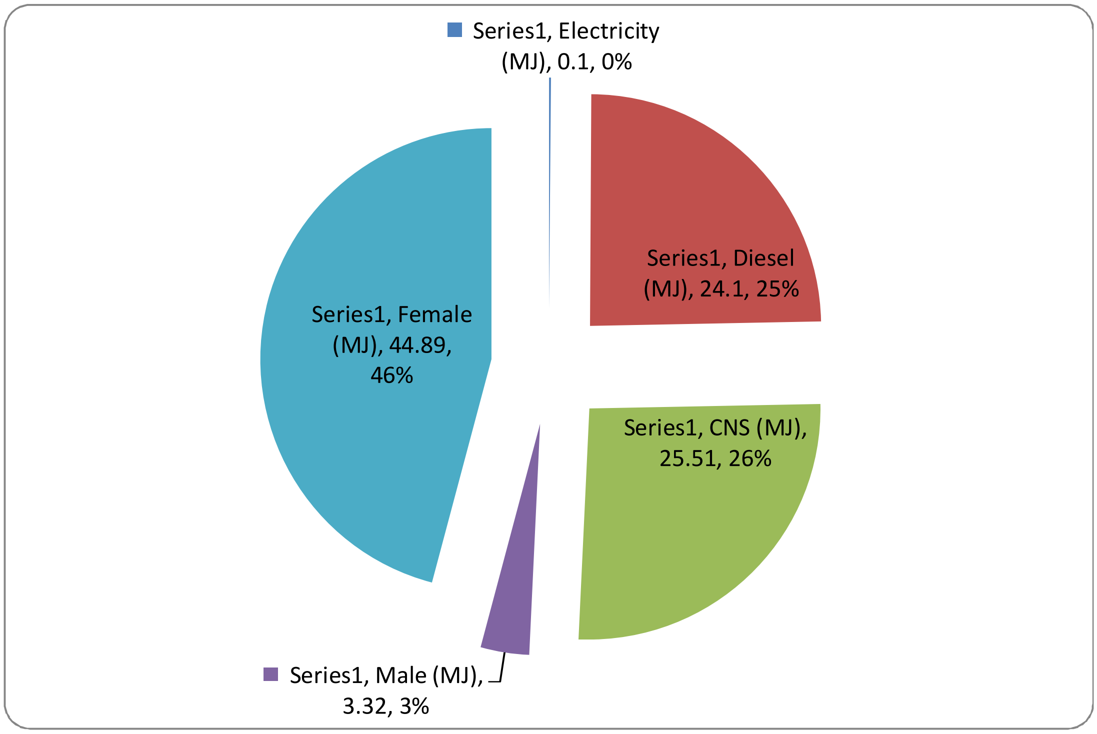

Figure 1: The Percentage of type of Energy Used

Table 4: Comparative analysis of energy utilization

Types of energy	**Energy utilized before conservation** MJ	**Percentage (%)**	**Energy utilized during conservation** MJ	**Percentage (%)**	**Difference between the two values** MJ
Electricity	11	0.01	3.10	0.14	7.9
Diesel	1069.9	0.71	542.24	24.61	527.66
CNS	0	0	573.79	26.04	-573.79
Fuel	148096	98.63	0	0	148096
Male	74.58	0.05	74.58	3.38	0
Female	1009.84	0.67	1009.84	48.83	0
Total	**150,155.32**	**100**	**2,203.55**	**100**	**148049.87**

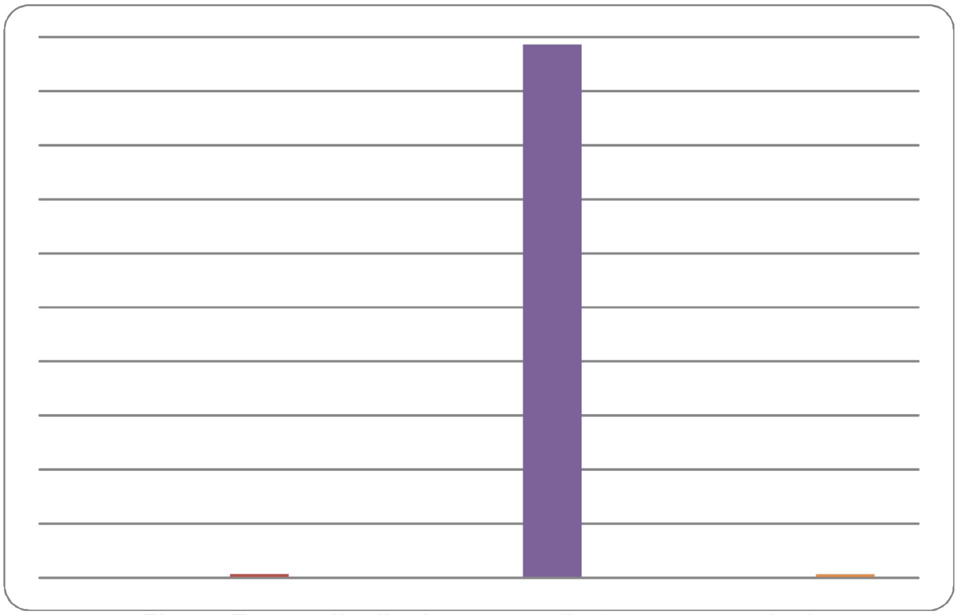

Fig 2a: Energy distribution pattern (before conservation)

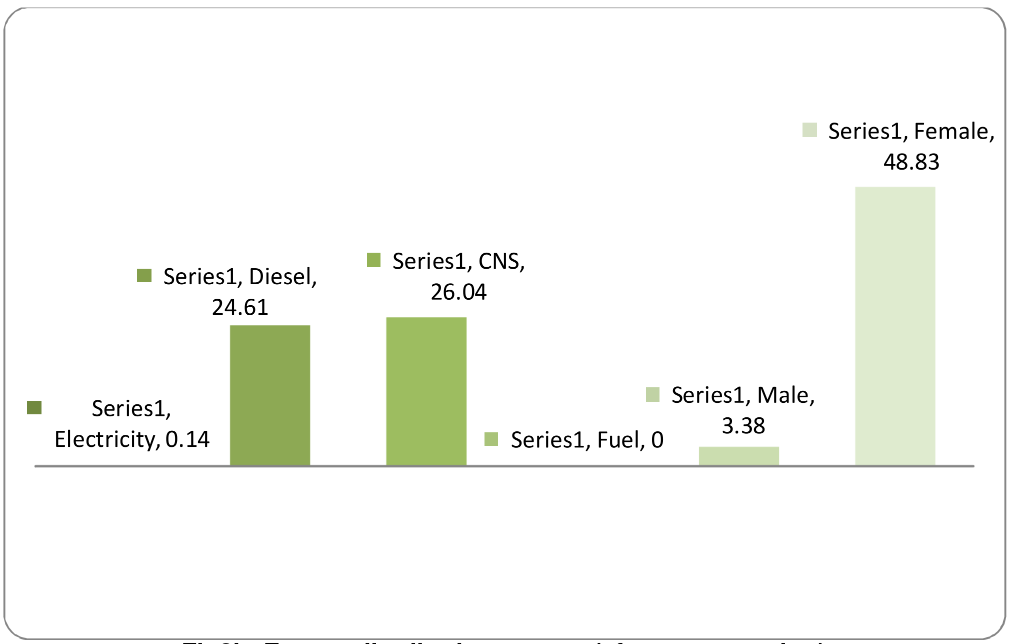

Fig2b: Energy distribution pattern (after conservation)

Economic environmental and social consideration:

The result obtained from the used of drying raw cashew nut unit operation using sun drying (Solar energy) using value reported from studies that Nigeria receives about 4.851 E 12 KWH (4.851E9MJ) of energy per day from the sun served as a means of conserving energy than the previous unit operation of soaking or condition as reported by Jekayinfa and Bamgboye (2006).. This is equivalent to about 1.0823 million tons of oil equivalent (mtoe) per day and is about 4 thousand times the current daily crude oil reduction and about 13 thousand times that of natural gas daily production based on energy unit by Okafor and Joe-Uzuegbu, 2010. Through this energy is conserved since sun are not paid for, it add little or no cost to the processing.

From previous studies by Ramachandra, 1998 it is noticed that the variation ranges from a minimum of 4.49kg fuel wood per kg of Cashew Kernel processed to the maximum of 8.66kg. Even with an evident that an industry with PPCU 52% consumes 8.32kg of fuelwood while an industry with a PPCU of 84% consume 4.49kg of fuel wood. Upon the fact that the fuelwood cost is relatively small in the processing of cash crop such as cashew compared to the value of the end product. From this study, it is evident that energy can be conserved in these industry by using cashew nut shell instead of fuelwood because total energy used to processed 1000kg of cashew nut to Kernel with 573.78kg cashew nut shells of the PPCU 50%. Since cashew nut shells were used to replace the fuelwood, savings in fuel wood cost of approximately $150 a month was obtained by Tippayawong et al (2010) earlier studies.

Substitution of fuelwood with cashew nut shells generated less waste; therefore, at present, there is no burning of cashew nut shells, hence no more complaints from neighbours are reported. But from this study more energy can still be conserved with the uses of cashew nut shells even though it is a waste product which are not needed and add not to the cost of production but better utilization of it can be obtained if steaming of raw nuts and drying of the Kernel which are the two energy intensive operations in this industry are work on by improving on tradition locally fabricated mud heating mantle should be used with an enclose chamber to maximize the heat transfer to the steam boiler over a suitable grate with a proper opening for primary and Secondary air to generate the highest combustion temperature and thus maximize the heat transferred to the trays. Proper insulation of the drier doors and a chimney of suitable height and diameter to create a draught and disperse smoke are the other essential components in cutting down the cashew nut shells consumption. Apart from these, the drier should be loaded fully.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The analysis of energy consumption and utilization carried out in this study showed that the renewable energy such as, sun and cashew nut shells (573.78kg) could be utilized as an alternative sources of energy in place of fuelwood (148,096kg) for drying of cashew nut. The percentage production capacity utilization, energy intensity, energy utilized from electricity, thermal energy from either diesel or cashew nut shells (CNS), manual energy supplied by male and female were 50%, 2.08MJ, 3.10MJ (0.1%), 542.24MJ (24.10%), 573.79MJ (25.51%), 74.85MJ (3.32%), and 1009.84MJ (44.89%), respectively. While energy utilized by the ten defined unit operations were 126.6MJ (5.63%), 2.97MJ (0.13%), 340.16MJ (15.12%), 162.72MJ (7.23%), 236.63MJ (10.52%), 777.29MJ (34.55%), 89.79MJ (3.99%), 218.02MJ (9.69%), 50.41MJ (2.24%), and 244.96MJ (10.90%), respectively. The different between the total energy utilized from comparative analysis before and after conserved energy were 150,155.32MJ and 2,203.55MJ respectively. This research work showed that conserving energy in cashew nut processing would bring good yield and reduced cost of production.

Recommendations

It is recommended that more research work should be carried out on the use of renewable energy as an alternative source of energy to conserve the amount of energy being consumed during cashew processing. That the locally fabricated mud heating mantle with an enclosed chamber over a suitable grate with a proper opening for primary and secondary channel to generate maximum heat transferred to the steam boiler and the trays for drying kernels.

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Cite this Article: Sodiq AR and Adeyemo AO (2015). Determinant of Gross Margin in Vegetable Production: Case Study of Iwo Zone of Osun State. Greener Journal of Agricultural Sciences, 5(4): 122-131, http://doi.org/10.15580/GJAS.2015.4.122912349.