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ENERGY ANALYSIS OF CASHEW NUT PROCESSING AGRO INDUSTRIES: A CASE STUDY

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Abstract

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The study was conducted to investigate the energy consumption pattern in small scale cashew nut processing industries located in Panruti taluk, Cuddalore district, Tamilnadu, India (Latitude 15º 11′ and 12º 35′; Longitude 78º 38′ and 80º 0′) . Three different small cashew processing industries based on the fuel used for drying of cashew kernel are considered for this study. The study compares the energy utilization, specific energy consumption and energy intensity of processing raw cashew nut. The energy input for drying of raw cashewnut, steaming, cooling and tempering, cutting and separation, drying of cashew kernel, kernel cooling, peeling of kernel and grading and packing were quantified using standard equation available in the literature. The total energy consumption for processing 1000 kg of raw cashew nuts were 5866.2 MJ, 5911.69 MJ, 6897.36 MJ for electrical drying, steam drying and biomass drying industries respectively. It was observed that 95% of energy is used for cashew kernel drying, raw cashew nut drying and steaming of raw nut. Energy intensity of cashew processing varied from 1.5 MJ/kg to 3 MJ/kg.

Key words: cashew processing unit, hybrid drying, energy cost, energy intensity, specific energy consumption

List of abbreviations: K – Efficiency of electric motor; P – Electric power consumed for particular operation; t_e – Time taken by electricity for a particular operation; I_{sc} – Average solar energy availability; A – Open sun drying area; T_s – Time taken for open sun drying; N – Number of persons involved in a particular operation; t_m – Manual time taken; C_f – lower heating value of fuel used for particular operation; W_f – quantity of fuel used for particular operation; Ec – Energy consumption (kw-hr); Pr – Production (kg); SEC – Specific energy consumption; EI – Energy intensity; PC – processing cost; E_{DR} – energy requirement for raw cashew nut drying; E_{SR} – energy requirement for steaming of raw cashew; E_{CT} – energy requirement for raw cashew nut drying; E_{CS-} energy requirement for cooling and tempering of steamed cashew nuts; E_{DK} – energy requirement for drying of kernel; E_{CK} – energy requirement for cooling of kernel; E_{PK} – energy requirement for peeling of kernel; E_{GP} – energy requirement for grading and packaging

Introduction

Energy is more important for development, employment generation and economic growth in rural agro industries.

Status of cashew processing industry in India and TN

Cashew is an important cash crop with rich source of protein (21.2%), carbohydrates (22%), fat (47%) and minerals (Calcium, Phosphorous and Iron) (Sharma, 2004) .Cashew tree is polygamous, tropical and subtropical and evergreen. It ranges in size from a small shrub in poor dry soil to a tree of 40 feet height in fertile soil and humid climate (Haripriya, 2014). India is among the largest processor of cashews nuts, next to Vietnam, Nigeria and Ivory Coast. The current production in the country accounts for 17% of the global production (FAOSTAT, 2010).

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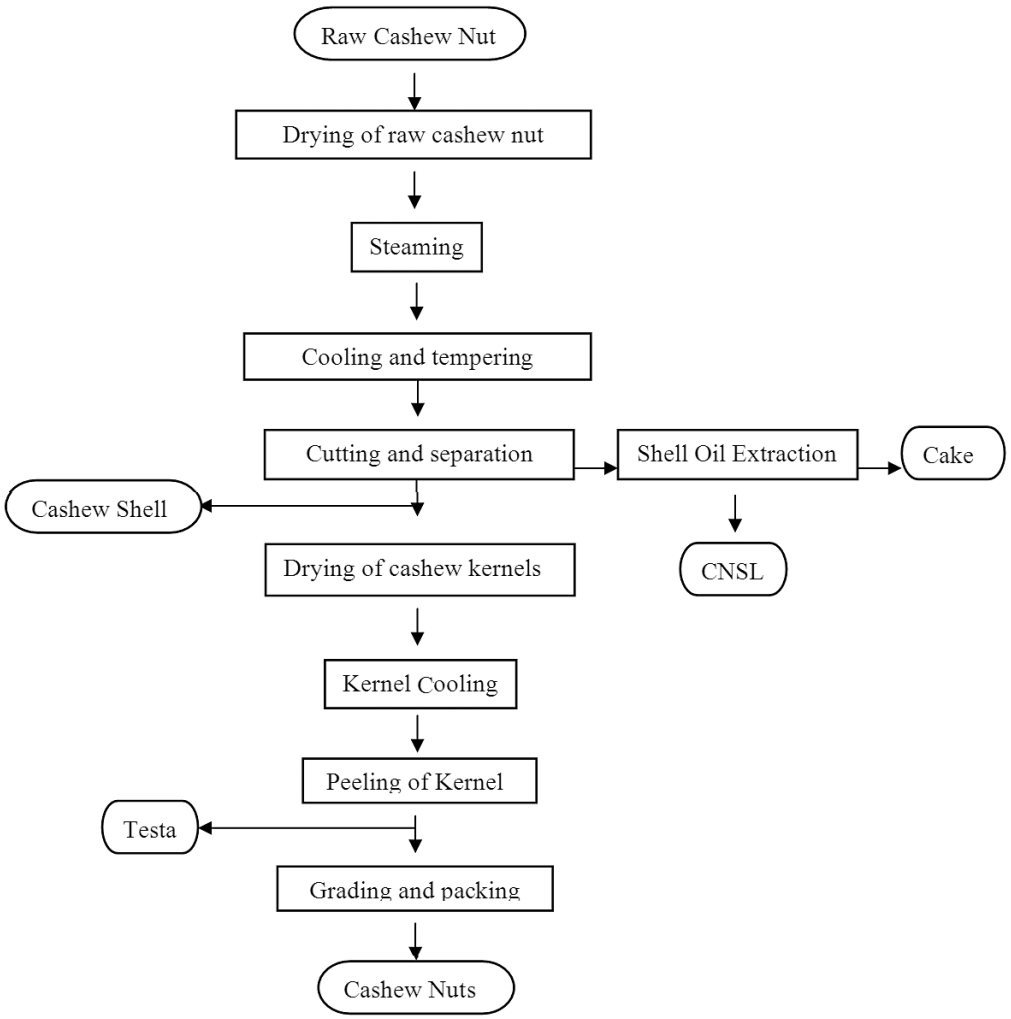
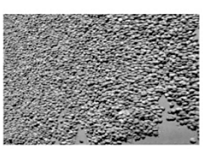
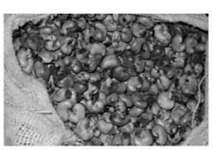
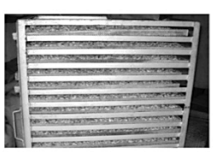


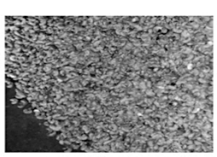

Drying of Raw Nuts


Steaming


Cooling and Tempering


Cutting and Separation


Drying of Kernels


Cooling


Peeling


Grading and Packing

Fig.1. Flow chart for various processes for drying cashew kernel

Also most of the cashew processing is carried out in small and medium units at rural level. The cashew process industry in India is largely an export-oriented which employs great number of women to process the nuts. Most of cashew nut (more than 70 percent) cultivation is carried out by small and marginal farmers (Anon, 2009). Cuddalore district in Tamil Nadu state was considered to have the maximum area and production under cashew than other cashew production districts in the state (Balamurugan et al., 2013). Cashew nut processing demands high labour and fuel requirements.The energy consumption cashew nut processing to produce same quantity of similar products revealed wide variation in energy intensity, ranging from 4.43 to 8.66 kg of fuel wood per kilogram of kernel (Atul et al., 2011)

Steps involved in small scale cashew nut processing

Cashew nut processing in India depends upon variety of raw materials, location, technological mechanization and availability of energy supply. The processing steps include drying of raw nuts, streaming the raw nuts, cooling, cutting to separate shell from kernel, drying the kernel, peeling, grading and packing. Based on the drying of cashew kernels, the cashew processing industries were categorized as electrical, biomass and stream industries (Atul et al., 2010) (Figure 1).

The main objective of cashew nut processing is to remove the valuable cashew kernel from the nut shell with little damage of cashew kernel. Figure 1 shows the various stages of cashew nut processing.

Raw cashew nuts

In raw state, the shell of the nut is leathery, not brittle. It contains thick vesicant oil. A thin testa skin surrounds the kernel. Cashew nut shell liquid (CSNL) is an important industrial raw material for resin manufacture and decorticating operation.

Drying of raw cashew nut

The raw cashew nut is dried for three days in open sun drying.

Steaming

After drying the raw cashew nut is entered into steaming process. The raw nuts are steamed at a pressure of 4.5–5 Kg/cm^2 for 20–30 minutes and then allowed to cool down for 24 hours.

Cutting and separation of shell

The shell can be cracked either manually, using a hammer or mechanically. The care must be taken while breaking the kernel and then during the separation of shell.

Drying of kernel

Once the kernel is removed from the shell, it is dried because kernel consists of brown layer at the outside known as "Testa". Drying takes usually six hours at temperature around 70°C.

Kernel cooling

To bring down the hot temperature under during drying process the kernel cooling process are carried out.

Peeling of kernel

The cooled kernels are undergone to peeling process. During this stage the testa is loosely attached to the kernel. Peeling of testa is done manually i.e., gently rubbing with fingers. Even though some testa will not be removed during the gentle rubbing so to overcome this, the testa is removed using the knife.

Grading and packing

Grading specifications (CEPC- cashew export & promotion council, India) are adopted for grading the cashew kernels. After grading the quality of the kernel is checked and the packing process is carried out.

Literature review

Atul mohod et al. (2010) conducted a study for the estimation of energy consumption of eight unit operation of small scale cashew nut processing in India. Among the eight unit operation, cashew nut drying, cashew nut steaming and drying of cashew kernels are identified as energy intensive process. This process consumes 90% of the total energy consumption.

Mohod et al. (2010) carried out energy analysis of baby boiler for steaming of cashew nut seeds. solar energy, electricity and fuel are the major source of energy consumed for cashew nut processing. Finally the results showed that while using electricity in the baby boiler for the steaming operation, for 60, 30 and 15 kg batch capacity industries, their corresponding total energy was estimated at 5321.43, 5540.14 and 6061.34 MJ.

These are the only literature available for energy conservation study of cashew nut industries in India. However the above study is done in Maharashtra state. The present study is carried out in Tamilnadu state to now the variation in energy consumption pattern of cashewnut processing industries.

Objective of the study

The increasing cost of energy has caused the food industry to examine means of reducing energy consumption in

processing. The study was conducted to estimate the energy consumption of three cashew processing industries using the energy audit tool with the following objectives:

■ To estimate the source wise energy consumption in unit operation of small-scale cashew processing industries.

■ To quantify the energy utilization and estimate the energy intensity of cashew processing operation.

■ To identify the disparities in the production of same quantity of similar product.

■ To establish the relationship between energy consumed and energy production in cashew nut processing industries.

■ To explore the possibilities of substitution of renewable energy based dryers in place of conventional dryers.

Materials and Methods

Study area

The primary data was collected from three small scale cashew processing industries located in the Panruti taluk of Cuddalore district, Tamilnadu, India. The total geographical area of the district is 3678 square kilometer with coastal line of 68 kilometer (Latitude 15º11' and 12º35' Longitude 78º 38' and 80º 0').The district has around 250-300 household cashew processing units, 25-30 medium sized export oriented units and 5 major large scale export oriented units (Figure 2).

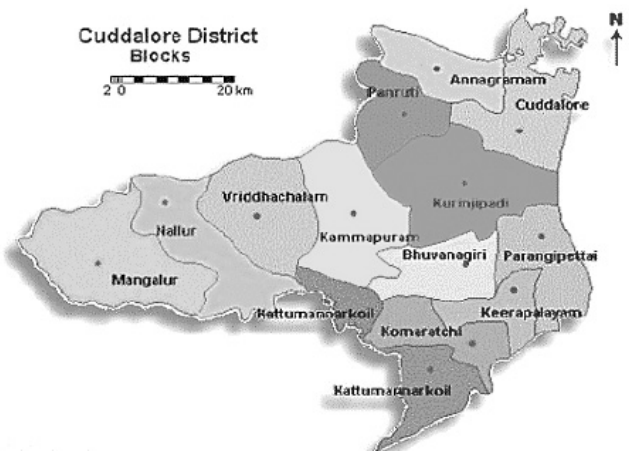


Fig.2. Location of Cashew processing industries in Cuddalore district

The details of the industries and their location are as follows:

Processing Unit 1

■ Name of the Industry: Thiruchannur Amman Cashews,Melmampattu

■ Mode of Processing: ELECTRICAL

■ Capacity: 1000 kg

Processing Unit 2

■ Name of the Industry: Murugan Industry, Sathipattu

■ Capacity: 1000 kg

■ Mode of Processing: STEAM (Thermal)

Processing Unit 3

■ Name of the Industry: Jothi Cashews, Sathipattu

■ Mode of Processing: BIOMASS

■ Capacity per batch: 1000 kg/batch

Energy utilization/Quantification in various unit operations

The energy consumption in cashew processing industry can be calculated based on the energy consumed in each unit operation expressed in an equivalent energy unit per kg of product. All materials and energy input (Thermal, electrical, manual and solar energy) for each unit operation is collected in standard format as per Table 1.

Energy analysis

The following equations were employed (Atul et al., 2010) to calculate energy consumption pattern of cashew nut processing industries. Unit operations considered were seed drying, steaming, cooling and tempering, cutting and separation, drying of kernels, cooling of kernels, peeling of testa, grading and packaging. The energy input at each stage of unit operations are expressed in terms of electrical, thermal and human energy.

Electrical Energy, $E_p = KPt_e$ (kWh);

Thermal Energy, $E_f = C_f W_f$ (J);

Manual Energy, $E_m = 0.075Nt_m$ (kWh);

Solar Energy, $E_s = I_{sc} AT_s$ (J).

Total energy consumption =

$= E_{DR} + E_{SR} + E_{CT} + E_{CS} + E_{DK} + E_{CK} + E_{PK} + E_{GP}$

Specific energy consumption (SEC)/Energy intensity (EI)

SEC is the energy consumed per unit (kW-hr) of production or energy per rupee of production. Energy Intensity is the ratio of energy consumption (kwhr) to the unit production (kg) or Quantity of energy required per unit of the product .It is the measure of energy efficiency of the product.

SEC = Ec/ Pr (Rs /kg)

EI = Ec /Pr (kwhr/kg)

Processing Cost (PC)

PC = EI x Electricity cost /kwhr

Results and Discussion

Material and energy flow

Material input and output in each unit operation are measured from the cashew processing units. Also the

energy input and fuel used for various operations are listed. The data obtained from the detailed energy audit of the three cashew processing industries are summarized in Table 2.

Most of energy and time are spent for drying of raw nuts, steaming of nuts and kernel drying.

Table 1
Data sheet for energy audit in Cashew nut processing industries

S.no	Unit Operations	Parameters Recorded	Energy component
1.	Drying of Raw Cashew Nuts	Input material (Kg) Drying Area (m^2) Output Material (Kg)(12% less) Drying Time (hr) Labor Engaged (man-hr) Solar Insulation (W/m^2)	Solar energy and Manual energy
2.	Steaming of Raw Cashew Nuts	Input material (Kg) Output material (Kg) Steaming Time (hr) Labor engaged (man-hr) Fuel used (kg) Calorific Value of fuel (KJ/Kg)	Electrical energy , Thermal and Manual energy
3.	Cooling and Tempering of Steamed Nuts	Input material (Kg) Cooling area (m^2) Output material (Kg) Time (hr) Labor Engaged (man-hr)	Manual energy
4.	Cutting and Separation of Steamed Nuts	Input material (Kg) Number of labors Cutting rate (Kg/hr) Labor engaged for cutting (man/day) Shelling rate (Kg/hr) Labor engaged for Shelling (man/day) Output Kernels (Kg) Output Shell (Kg)	Manual
5.	Drying of Cashew Kernels	Input material (Kg) Output material (Kg) Drying time (hr) Labor engaged (man/day)	Electrical energy , Thermal and Manual energy
6.	Kernel Cooling	Input material (Kg) Cooling Area (m^2) Output material (Kg) Cooling Time (hr) Labor Engaged (man/day)	Manual
7.	Peeling of Kernel	Input material (Kg) Output material (Kg) Peeling rate (Kg/hr) Labor engaged for peeling (man/day)	Manual
8.	Grading and Packaging	Input material (Kg) Grading rate (Kg/hr) Labor engaged for grading (man/day) Packaging rate (Kg/day) Labor engaged for packaging(man/day)	Manual

Table 2

Materials and Energy flow pattern in three different industries

S.No	Unit Operations	Parameters Recorded	Electrical based unit	Steam based unit	Biomass based unit
1.	Drying of Raw Cashew Nuts	Input material (Kg)	1000	1000	1000
		Drying Area (m^2)	54	56.25	67.5
		Output Material (Kg)(12% less)	880	860	865
		Drying Time (hr)	24	24	24
		Labor Engaged (man-hr)	2 × 8	2 × 8	2 × 8
		Solar Insulation (W/m^2)	810	830	850
2.	Steaming of Raw Cashew Nuts	Input material (Kg)	880	860	865
		Output material (Kg)	888	866	872
		Steaming Time (hr)	0.416	0.416	0.416
		Labor engaged (man-hr)	2 × 8	2 × 8	2 × 8
		Fuel used (kg)	75	75	75
		Calorific Value of fuel (KJ/Kg)	17 000	17 000	17 000
3.	Cooling and Tempering of Steamed Nuts	Input material (Kg)	888	866	872
		Cooling area (m^2)	9	9	9
		Output material (Kg)	880	860	865
		Time (hr)	12–15	12–15	12–15
		Labor Engaged (man-hr)	2 × 8	2 × 8	2
4.	Cutting and Separation of Steamed Nuts	Input material (Kg)	880	860	865
		Number of labors	6 l	6	6 l
		Cutting rate (Kg/hr)	5	5.6	4 d
		Labor engaged for cutting (man/day)	6	6	35
		Shelling rate (Kg/hr)	12.25	11.87	6
		Labor engaged for Shelling (man/day)	9	9	96
		Output Kernels (Kg)	185	181	9
		Output Shell (Kg)	695	679	182
5.	Drying of Cashew Kernels	Input material (Kg)	185	181	683
		Output material (Kg)	178	174	182
		Drying time (hr)	4-6	7	175
		Labor engaged (man/day)	1	1	8
6.	Kernel Cooling	Input material (Kg)	178	174	175
		Cooling Area (m^2)	3.6	3.6	3.6
		Output material (Kg)	178	174	175
		Cooling Time (hr)	12	12	12
		Labor Engaged (man/day)	1	1	1
7.	Peeling of Kernel	Input material (Kg)	178	174	175
		Output material (Kg)	160	157	158
		Peeling rate (Kg/hr)	5	5	5
		Labor engaged for peeling (man/day)	5	5	4
8.	Grading and Packaging	Input material (Kg)	160	157	158
		Grading rate (Kg/hr)	7	7.5	6.25
		Labor engaged for grading (man/day)	3	3	3
		Packaging rate (Kg/day)	60	60	60
		Labor engaged for packaging(man/day)	3	3	3

Energy consumption pattern

The energy requirement for Drying of raw nuts, Steaming of raw nuts, Cooling of nuts, Cutting and separation, Cashew kernel drying, cooling of Cashew kernel, Peeling of Cashew kernel, Grading and packaging were 3879 MJ, 1287 MJ ,12 MJ, 71 MJ, 577 MJ, 3 MJ, 25 MJ, 7 MJ respectively in steam based cashew processing unit. Thus the total energy consumption for processing 1000 kg of raw cashew nut was 5866.2 MJ which is

equivalent to 5.8 MJ/kg. Similarly the total energy consumption of other two cashew processing units was found to be 5911.69 MJ and 6897.36 MJ. The total .energy consumption of the three industries are shown in Tables 3-5. The following three unit operations are identified as energy intensive viz Sun drying of raw nuts, steaming of raw nuts and drying of cashew kernel. Since solar energy is freely available, the energy cost associated with the sun drying of raw nuts is negligible. Steaming of raw cashew nuts contributes about 23%, 21% and 16% of the total energy consumption in the above three processing units.

The next energy intensive process, drying of cashew kernels contributes to about 9.8%, 7.6% and 7.42% of the

Table 3
Total Energy Consumption of electrical based drying industries

Type of industry: Electrical drying of cashew kernel (MJ/1000 kg raw nuts/ 180 kg batch)					
Unit operation	Solar	Biomass	Electrical	Manual	Total
Drying of raw nuts	3866.90	–	–	12.96	3879.86
Steaming of raw nuts	–	1275	–	12.96	1287.96
Cooling of nuts	–	–	–	12.96	12.96
Cutting and separation	–	–	–	71.28	71.28
Cashew Kernel drying	–	–	575.64	1.62	577.26
Cooling of Cashew kernel	–	–	–	3.24	3.24
Peeling of Cashew kernel	–	–	–	25.92	25.92
Grading and packaging	–	–	–	7.2	7.2
Total energy	3866.90	1275	575.64	148.14	5866.2
Percentage Energy	65.9%	21.75%	9.8%	2.52%	100%

Table 4
Total Energy Consumption of steam based drying industries

Type of industry: Steam drying of cashew kernel (MJ/1000 kg raw nuts/ 180 kg batch)					
Unit operation	Solar	Biomass	Thermal	Manual	Total
Drying of raw nuts	4033.8	–	–	12.96	4046.76
Steaming of raw nuts	–	1275	–	12.96	1287.96
Cooling of nuts	–	–	–	12.96	12.96
Cutting and separation	–	–	–	71.28	71.28
Cashew Kernel drying	–	–	448.0	1.89	449.89
Cooling of Cashew kernel	–	–	–	3.24	3.24
Peeling of Cashew kernel	–	–	–	32.4	32.4
Grading and packaging	–	–	–	7.2	7.2
Total energy	4033.8	1275	448.0	154.89	5911.69
Percentage Energy	68.23%	21.56%	7.57%	2.62%	100%

Table 5
Total Energy Consumption of biomass based drying industries

Type of industry: Biomass drying of cashew kernel (MJ/1000 kg raw nuts/ 180 kg batch)					
Unit operation	Solar	Biomass	Electrical	Manual	Total
Drying of raw nuts	4957.2	–	–	12.96	4970.16
Steaming of raw nuts	–	1275	–	12.96	1287.96
Cooling of nuts	–	–	–	12.96	12.96
Cutting and separation	–	–	–	71.28	71.28
Cashew Kernel drying	–	510	–	2.16	512.16
Cooling of Cashew kernel	–	–	–	3.24	3.24
Peeling of Cashew kernel	–	–	–	32.4	32.4
Grading and packaging	–	–	–	7.2	7.2
Total energy	4957.2	1785	–	155.16	6897.36
Percentage Energy	71.87%	25.87%	–	2.25%	100%

total energy consumption in the above three processing units. There is ample scope of energy conservation/savings through renewable energy systems. The cost of drying per unit of the product is varying between Rs 4-5/kg .Renewable energy based drying systems like solar drying and Hybrid drying can contribute to the reduction in drying cost (Debbarma et al et al.,2013; Dhanushkodi et al.,2014a,b).

Energy intensity/Specific Energy Consumption

The comparison of total energy consumption in each unit operation of three industries are presented in Figure 3. Energy analyses were carried out to predict the energy intensity and specific energy consumption (SEC) variation in these industries. SEC ranges from 8 kwhr/kg of cashew kernel to the maximum of 10.64 kwhr/kg. The high level of energy consumption may be due to the non-utilization of the Installed capacity. However the energy cost associated with the processing of cashew nut may be comparatively lesser than the value of end product. Most of these industries perform steaming operation with burning of wood and electricity. The specific energy consumption of steaming and cashew kernel drying can be reduced by use of energy efficient equipments, alternative technologies, energy conservation and fuel switching. Efficient usage of fuel and renewable energy based drying system can contribute to the reduction of production costs.

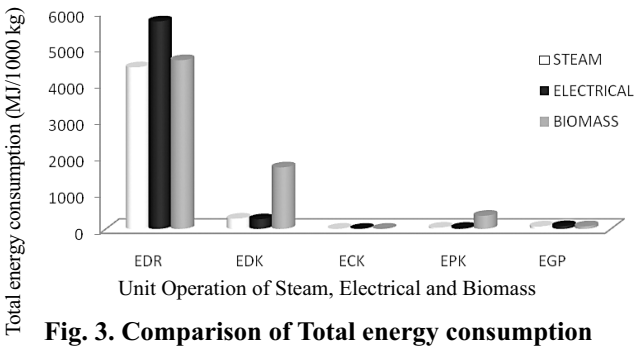


Fig. 3. Comparison of Total energy consumption

Conclusion

The following important conclusions are drawn from the case study of energy audit of cashew nut processing industries.

Energy intensity for the production of cashew kernel was estimated to be 265.68 MJ, 448 MJ and 510 MJ for electrical, steam and biomass based industries respectively.

Difference of 356 MJ, 786 MJ and 1342 MJ was observed among Industries with same production capacity of 1000 kg raw nut

The difference in energy intensity may be attributed to the fuel source, processing method and processing equipment.

Energy required to process 1000 kg of cashew kernel into cashew nuts was 300 MJ

There is a vast potential of meeting the energy requirement of cashew processing industries through renewable energy based technologies

Acknowledgement

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