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Energy Investigation and Conservations of Condiment Produced From Bambara Nut (*Vigna Subterranean*)

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ABSTRACT *:* The investigation on energy requirement and conservation approaches of condiment produced from bambara nut was the aim of this paper since it provides information on energy involved during commercialization and for researchers. Data on energy utilization and conservation patterns were obtained based on time taken, gender involved and quantity and sources of energy using standard energy equations. A total of 36.56±1.73MJ/kg where thermal energy accounted for 82% and manual energy amounting to 18% were the only forms of energy used during production process. Conservation approach I resulted in mean energy of 25.64±1.73MJ/kg where electrical energy, manual energy and thermal energy accounted for 1.49MJ (6%) 4.40 MJ (17%) and 21.04MJ (77%) respectively. Conservation approach II conserved the energy further to 24.41±1.73MJ/kg as the operation was thermal energy dependent, followed by manual and electrical energy with energy values of 18.54, 4.38 and 1.49MJ equivalent to 76%, 18% and 6% accordingly. Boiling and drying were identified as the most energy demanding operations while soaking was the least consuming energy operation at all levels. However, conservation approach II where LPG was used during boiling operation allows energy reduction to be 33.25% when compared with production process in converting bambara nut into condiment.
Keywords: Bambara nut, condiment, conservation approach, energy, production process

INTRODUCTION

The state of industrialization can be accessed from the pattern and consumption quality of its energy. Thus, energy is one of the most critical input resources in the manufacturing industries (Fadare et al., 2009). Cost-effectiveness and reduction in industrial consumption can be achieved using good energy management practices and energy-efficient equipment (Aiyedun et al., 2008; Noah et al., 2012).The benefits are reflected directly in organization's profitability while also making contribution to global environmental improvement in terms of energy conservation (Jekayinfa, 2006).

Energy is referred as one of the most important resources of any country. It is a known fact that high rate of industrial growth of any country is a function of the amount of energy available in that country and the extent to which this energy is utilized. Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Uninterrupted energy supply is a vital issue for all countries today. In Nigeria, among the urban dwellers, kerosene and gas are the major cooking fuels. The majority of the people rely on kerosene stoves for domestic cooking, while only a few use gas and electric cookers (Abiodun, 2003). Traditionally, energy is treated as an intermediate input in the production process. In Nigeria, there is inefficient energy utilization and its corresponding environmental impart. Therefore, there is a need to understand energy and energy systems. Several research have been reported on the energy consumption of different agricultural process operations both within and outside Nigeria (Aiyedun and Onakoya, 2000) but food processing factories have little or no idea of the energy consumption pattern which makes monitoring, improvement and efficiency difficult (Jekayinfa and Olajide, 2007).

In spite of this occurrence, some reports on energy audit and survey have been published on processing of palm oil (Akinoso and Omolola, 2011), sugar beet production (Mrini et al., 2002), cashew nut processing and palm kernel processing (Jekayinfa and Bamgboye, 2006 and 2007), cowpea flour production (Akinoso et al., 2013) and condiment from locust beans (Akinoso and Adedayo, 2012) among others. However, energy quantification and conservation is not evident on condiments produced from bambara nut despite several researches on the legumes. Research has indicated that bambara nut contains 16% crude protein, 9.7% moisture, 5.9% crude fat, 2.9% ash and 64.9% total carbohydrate (Aremu et al., 2006). It contains an appreciable amount of lysine and a minimum amount of trypsin and chymotrypsin as reported by (Ijarotimi and Esho, 2009). The high carbohydrate (65%) and relatively high protein 18% content of bambara groundnut makes it a complete food (Doku, 1995). Large quantity of the beans is produced annually in Eastern and Northern part of Nigeria due to relatively cheap production cost. Barimalaa et al. (1994) and Ademiluyi and Oboh (2011) reported the production of condiments from bambara nut without quantifying the energy involved.

This paper seeks to quantify and conserve the energy utilization during the production of the bambara nut condiment.

2. MATERIALS AND METHODS

One kilogram (1kg) of raw material was used for each level of production of the condiments. Information on energy utilization and conservation were obtained on basis of unit operations, quantity of fuel used, time taken, gender involved and sources of energy used (Table 1). Obtained data were subjected to descriptive analysis using SPSS software at 5% significance level. Means were reported for each unit operations.

2.1 Production process

Procedure reported by Ademiluyi and Oboh (2011) was slightly modified for the production of condiment from bambara nut. Bambara nut was weighed, sorted, winnowed (as preliminary operations), washed and soaked overnight. The soaked seeds were dehulled by mashing the seeds in a wooden mortar, and further rubbing the cotyledons between palms of the hands and subsequent washing with potable waters to remove the hulls. The cotyledons were boiled in a cast iron pot for 1h using air dried wood as source of heat until adequately softened; boiling water was drained using plastic sieve. Drained cotyledons were spread on already cleaned banana leaves then wrapped in polythene bag and placed in an air tight container for spontaneous fermentation for the period of 4 days at ambient temperature.

2.2 Conservation approaches

The conservation approaches were done by replacing cast iron pot during the production process with aluminium pot. The overnight soaking was substituted with 24 hours soaking, while the boiling operation with firewood was carried out with the use of kerosene and liquefied propane gas (LPG) during conservation I and II approaches respectively. Other unit operations remain the same at all levels. Drying, milling and high density polyethylene were introduced during the conservation processes to improve marketability, storability, acceptability and quality of the products.

2.3 Energy Quantification

Energy utilization during each operation was categorized as electrical, thermal, and manual energy as represented in equation (1-3). These modes of energy were estimated using approach adopted by (Akinoso and Adedayo, 2012) during energy utilization pattern of converting African Locust beans (*Parkia biglobosa*) into condiment.

2.3.1 Manual Energy

Manual energy was estimated based on the values recommended by (Goyal et al., 2012) as given in equation (1)

$E_m = 0.75 \times N \times T_a$ (Kw) Equation 1

Where 0.75 = the average power of a normal human labour in kW, N = number of person involved in the operation; and Ta = useful time spent to accomplish a given task in hours.

2.3.2 Thermal Energy

Thermal energy was estimated according to the heating source used (Rajput, 2001) as expressed in Equation 2.

$E \alpha W$ (Rajput, 2001)

$E = CfW(MJ)$ Equation 2

Where Cf, is the constant of proportionality which represents the calorific value (heating value) of fuel used, W is the quantity of fuel consumed and E is the quantity of energy consumed. Calorific Value of Typical Air Dried Wood (15MJ/kg), Kerosene (43.7 MJ/L), Liquefied Propane Gas (LPG) (50.35MJ/kg) and charcoal (27MJ/kg).

2.3.3 Electrical Energy

Equipment using electrical energy, the rated horse power of each motor was multiplied by the corresponding hours of operation (Equation 3). A motor efficiency of 80% was assumed to compute the electrical input (Rajput, 2001).

$Ep = \Delta \times P \times N$ Equation 3

Where Ep is the electrical energy consumed in kWh= kJ, P is the rated power of motor in kW (dehuller, 4.48; Attrition Mill, 2.98 and Impulse sealer, 0.26), N is the time spent during the operation, Δ is the power factor (assumed to be 0.8).

2.4. Total Energy Estimation (En)

This was calculated by summation of all energy of each unit operation involved during the production of each condiment for production process and conservation approaches as related in equation 4 and 5.

2.4.1 Production Process

$En= E_{PO}+ E_S+ E_D+ E_B+ E_W+ E_F+ E_P$ (Equation 4)

Where E_{PO}, $E_{S,}$ $E_{D,}$ $E_{B,}$ $E_{W,}$ E_F and E_P are energy for preliminary operation, soaking, dehulling, boiling, wrapping, fermentation and packaging

2.4.2 Conservation Approach

$En= E_{PO}+ E_S+ E_{MD}+ E_{WA}+ E_B+ E_W+ E_F+ E_D+ E_M+E_P$ (Equation 5)

Where E_{PO}, Es, $E_{MD,}$ $E_{WA,}$ $E_{B,}$ $E_{W,}$ $E_{F,}$ $E_{D,}$ $E_{M,}$ and E_P are energy for preliminary operation, soaking, mechanized dehulling, washing, boiling, wrapping, fermentation, drying, milling and packaging respectively.

3. RESULTS AND DISCUSSION

3.1 Energy requirement during production process of bambara nut condiment.

The total energy utilized during production process was 36.56±1.73 as presented in Table 2. The energy consumed during this operation was higher than the energy utilized during extraction of crude soybean oil 2.38MJ/kg (Wang, 2009); 14.98MJ/kg utilized in cottage palm oil mill (Akinoso and Omolola, 2011); 7.20 MJ/kg for palm oil production using electrical energy (Mahlia et al., 2001). However, energy consumption of this process was less when compared with energy utilization of condiment from locust beans (*Parkia biglobosa*) (59.82±1.4MJ/kg) (Akinoso and Adedayo, 2012). The dichotomy may be traced to crop physiology such as hardness of seed coat, technology utilized, energy sources and quantity of sample used. 0.06MJ was used during soaking while 31.50MJ was utilized during boiling operation corresponding to 0.16% and 86.15%. These two operations represent least and most energy demanding operations. Also, more than threefold of the energy input was due to boiling while manual dehulling contributed 10% and less than 5% representing a least fraction of the energy input was due to preliminary operations, soaking, wrapping, fermentation and packaging. During the production process, thermal energy and manual energy were the forms of the energy used accounting for 82% and 18% respectively.

3.2 Energy used by the conservation approaches

This process involved utilization of kerosene during boiling operation in conversation approach I, condiment produced during this operation consumed a total of 25.64±1.73 as against 36.56±1.73MJ consumed during the production process counterpart (Table 2). The reduction in energy consumption can be attributed to change in energy source from firewood to kerosene, change in cooking pot from mild steel to aluminium and manual dehulling being replaced with mechanical dehulling which justified variation in energy intensity when compared with production process method. The drying operation utilized 16.29MJ corresponding to 63.53% while 0.06MJ was consumed during soaking amounting to 0.23% making the operations most and least energy intensive operations. Drying and boiling operation represent the two thermal operations representing 21.04MJ which accounted for over three-quarter (82.03%) of the total energy input while preliminary operations, soaking, washing, wrapping and fermentation consumed a total of 2.12MJ and 2.36MJ was expended during mechanized dehulling, milling and packaging. It is worthwhile to note that, thermal energy, manual energy and electrical energy accounted for 21.04MJ, 4.40 MJ and 1.49MJ amounting to 77%, 17% and 6% respectively.

During conservation approach II where LPG was used during boiling operation. Energy intensity of the condiment was estimated to be 24.41±1.73MJ as against 25.64±1.73MJ and 36.56±1.73MJ expended during conservation approach I and production process method (Table 2). A further reduction in energy consumption can be attributed to change in fuel source from kerosene to LPG and other operations were the same as applicable to conservation approach I. Thermal operations (drying and boiling operation) consumed 19.81MJ which accounted for over three-quarter (81.20%) of the total energy input. Preliminary operations, washing, wrapping and fermentation consumed 0.11MJ, 0.84MJ, 1.01MJ and 0.09MJ corresponding to 0.43, 3.44 4.12 and 0.37% respectively. Thermal energy was the most consuming form of energy used followed by manual energy and electrical energy with the energy values of 18.54MJ, 4.38MJ and 1.49MJ corresponding to 76%, 18% and 6% respectively.

3.3 Energy used during levels of processing bambara nut into condiment.

Energy expended during production process was 36.563±1.732MJ, 25.64±1.73MJ was utilized during conservation approach I and 24.41±1.73MJ was consumed during conservation approach II (Table 2). The energy utilized was significantly different from one another ($P > 0.05$). This was attributed to the fact that air dried wood fuels are less efficient as their utilization tend to have low efficiencies (about10%) with 15MJ/kg calorific value hence a large quantity is required to achieve the heating process (POST, 2002) and thus making production process more energy intensive. Conservation approach I which utilized kerosene as fuel consume more energy with calorifc value (43.7MJ/L) next to production process because the release of energy from this fuel is dependent on the technological advancement of appliance use while conservation approach II which utilized liquefied propane gas (LPG) as fuel consume the least energy with calorifc value (50.35MJ/kg) because high proportion of its energy content is converted to heat. Statistical analysis ($P > 0.05$) indicated that energy demand during preliminary operation, wrapping, fermentation and soaking was not significantly different from each other in all the three processes. Energy utilized by manual dehulling in production process was 3.42MJ corresponding to 9.35% of the total energy input. The energy utilized by manual dehulling was higher than energy expended during conservation approaches I and II where locally fabricated mechanized dehuller was used for both process, this is as a result reduction in dehulling time, the energy and their corresponding percentage were 1.27±0.01MJ, 1.27±0.01MJ, 4.96% and 5.21% for conservation approaches I and II respectively. Similar observation was reported on Africa locust beans (Akinoso and Adedayo, 2012).

Washing was introduced during improved processes as a result of need to separate the hulls from the cotyledons although the operation was carried out simultaneously during manual dehulling in production process. Significant differences were not established in both improved processes. Drying and milling operation consumed 16.29±1.95MJ and 0.66±0.14MJ corresponding to 63.53% and 2.58% respectively in conservation approaches I and 16.29±1.95MJ and 0.66±0.14MJ corresponding to 66.75% and 2.71% respectively in conservation approaches II as these operations were not applicable to production process. There were no significant differences between the conservation approaches for drying and milling operations at ($p > 0.05$). These operations were added to improve the marketability, acceptability and storability of the product produced.

Energy required for packaging in conservation approaches I and II were 0.99MJ and 0.377MJ for production process. There was no significant difference in energy utilization during packaging at ($p > 0.05$). This can be traced to insignificant electrical energy input that was utilized for packaging in the conservation approaches I and II.

4 CONCLUSION

Production process utilized highest energy followed by conservation approach I and conservation approach II was least in energy demand for bambara nut condiment. 5% energy conservation was attained when compared with conservation approach I. Conservation approach II saved 33.25% of energy input when compared with production process in bambara nut processing into condiment.

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Table 1 Measured parameters for evaluating energy consumption and conservation approach I and II during processing of bambara nut into condiment

Unit Operation	Required Parameters	Production Process	Conservation Approaches
Preliminary Operations	Number of persons involved	1	1
	Time taken (h)	0.15h	0.14h
Soaking	Number of persons involved	1	1
	Time taken for soaking	0.08h	0.08h

Dehulling and Washing	Number of persons involved	2	-
	Time taken (h)	2.28h	-
Mechanized Dehulling	Number of persons involved	-	2
	Time taken (h)	-	0.25h
Washing	Number of persons involved	-	2
	Time taken (h)	-	0.56h
Boiling	Air dried wood consumed l	2kg	-
	Fuel consumed l (kerosene)	-	0.1L
	Fuel consumed (LPG)	-	0.06kg
	Number of Persons involved in boiling	2	1
	Time taken for boiling (h)	1h	0.5h
Wrapping	Number of persons involved	2	2
	Time taken (h)	0.67h	0.68h
Fermentation	Number of persons involved	1	1
	Time taken (h)	0.12h	0.12h
Drying	Number of persons involved	-	2
	Time taken (h)	-	0.6h
Milling	Number of persons involved	-	2
	Time taken (h)	-	0.17h
Packaging	Number of persons involved	2	2
	Time taken (h)	0.25h	0.25h

Table 2 Energy quantification during condiment produced from bambara nut

Unit Operation	Production Process		Conservation Approach I		Conservation Approach II	
	Energy(MJ)	Percentage	Energy(MJ)	Percentage	Energy(MJ)	Percentage
Preliminary	0.11 ± 0.03^{a}	0.31	0.11 ± 0.03^{a}	0.41	0.11 ± 0.03^{a}	0.43
Soaking	0.06 ± 0.01^{a}	0.16	0.06 ± 0.02^{a}	0.23	0.06 ± 0.01^{a}	0.25
Washing	NA		0.84 ± 0.06^{a}	3.28	0.84 ± 0.06^{a}	3.44
Dehulling	3.42 ± 0.04^{a}	9.35	1.27 ± 0.01^{b}	4.96	1.27 ± 0.01^{b}	5.21
Boiling	31.50 ± 2.89^{a}	86.15	4.75 ± 1.15^{b}	1.50	3.52 ± 0.87^{b}	14.43
Wrapping	1.01 ± 0.03^{a}	2.75	1.02 ± 0.01^{a}	3.98	1.01 ± 0.02^{a}	4.12
Fermentation	0.09 ± 0.02^{a}	0.25	0.09 ± 0.01^{a}	0.35	0.09 ± 0.01^{a}	0.37
Drying	NA		16.29 ± 1.95^{a}	63.53	16.29 ± 1.95^{a}	66.75
Milling	NA		0.66 ± 0.14^{a}	2.58	0.66 ± 0.14^{a}	2.71
Packaging	0.38 ± 0.03^{a}	1.03	0.43 ± 0.14^{a}	2.19	0.56 ± 0.13^{a}	2.30
Total	36.56 ± 1.73^{a}		25.64 ± 1.73^{b}		24.41 ± 1.73^{b}	

*NA= Not Applicable; Means followed by different letters across the rows are significantly different ($p<0.05$) from one another