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A Comparative Study of Energy Demand of Instant- Pounded Yam Flour Production Methods

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Abstract
Traditionally, method of producing pounded yam by pounding cooked yam using pestle and mortar is time and labour consuming, thus discouraging consumption of the food among urban elite. Conversion of yam tubers to instant-pounded yam flour requires quantifiable magnitudes. Therefore, the objective of this study was to determine energy conservation potentials of the established three instant-pounded yam flour methods of production. Data were collected from nine instant-pounded yam flour producing factory using structured questionnaires, oral interview, and direct measurement of processing parameters. The data were fit into standard equations to estimate energy demand. Energy required for processing 1000 kg of yam to instant-pounded yam flour using cooking method, steaming method and wet-milling methods were 6720.15MJ, 6934.48MJ and 4296.56MJ respectively, equivalent to 6.7 MJ/kg, 6.9 MJ/kg and 4.3 MJ/kg respectively. Energy intensity for peeling, washing, slicing and packaging were 0.0055 MJ, 0.003 MJ, 0.0076 MJ and 0.2 MJ respectively, and are the same for all the methods studied. Drying consumed more than half of the total energy requirements in each method; cooking (66.26%), steaming (79.04%) and wet-milling methods (76.57%). Using energy demand as criterion, wet- milling method is recommended.
Keywords: Instant-pounded yam flour, production method, energy demand, energy pattern.

1.0 Introduction

Yams (Dioscorea spp) constitute a nutritious, high carbohydrate and fibre food source. Other nutrients present in yam are caloric proteins, minerals and vitamins (Osunde, 2009). They are also important in household food security, diet diversification, employment and income generation as well as alleviation of poverty. Yams are characterized by high moisture content, which renders the tubers more susceptible to microbial attacks and brings about high perishability of the tubers. With annual production of above 28 million metric tonnes (FOS, 2011), Nigeria is the world's largest producer of edible yams, with D. rotundata and D. alata as the two most cultivated yam species in the country. Yam is a staple food that is consumed as cooked, fried or pounded. Industrial processing and utilization of yam includes starch, poultry and livestock feed, production of yam flour and instant-pounded yam flour production. Traditionally, method of producing pounded yam, a staple food, by pounding cooked yam using pestle and mortar is time and labour consuming. This discourages consumption of the food among urban elite. Instant-pounded yam flour is a suitable alternative. Instant pounded yam flour reduces processing time and human drudgery associated with pounded yam production (Akinoso and Olatoye 2013). Three distinct methods have been reported for instant- pounded yam flour production. Peeling, washing, steaming, drying, milling and packaging (Aworh, 2010), peeling, washing, cooking, drying, milling and packaging (Olorunda et al,1977) and peeling, washing, wet-milling, drying, milling and packaging ,(Ofi, 2005).

The food industry is one of the energy-intensive industries and lacks information on energy conservation and conversion technologies (Wang, 2009). Economic growth and development of any nation relies greatly on energy availability, management and conservation (Jesuleye 1999). Energy conservation is important because of the limited and expensive nature of non-renewable energy sources (Daniel, 2010). Energy efficiency practices and products will reduce cost of production (Akinoso and Olatoye 2013). Energy efficiencies in food processing facilities vary with end users and production lines. Procedural and behavioural changes that include avoiding wastages can save about 30% energy without capital investment (Fischer et al., 2007). Some reported work on energy utilization in food industry are sugar-beet production (Mrini et al., 2002), bread baking (Jekayinfa, 2007), cassava products processing operations (Jekayinfa and Olajide, 2007), palm-kernel oil processing operations (Jekayinfa and Bamgboye, 2007), bread making processes (Le-bail et al., 2010), sugar production factory (Abubakar et al., 2010), and cashew nut processing mills (Atul et al., 2010).

Conversion of yam tubers to instant-pounded yam flour requires quantifiable magnitudes and different forms of energy that includes thermal, mechanical, electrical and manual energies. Omission of unnecessary unit operations can contribute significantly to energy conservation potential of a particular processing technology (Muhammad 2009). Therefore, the objective of this study was to determine energy conservation potentials of the established three instant-pounded yam flour methods of production.

2.0 Materials and Methods

2.1 Research instruments

Research instruments employed in this study were structured questionnaires, oral interview and direct measurements techniques. Data were collected from nine (three for each method) instant-pounded yam flour producing factory on processing parameters, unit operations involved, production capacity, equipment used, sources of energy, time taken, gender and number of labour requirements for processing 1000 kg of yam into instant-pounded flour. Mean values were recorded as data obtained. All data obtained were subjected to descriptive statistical analysis and ANOVA at 5% level of significance.

2.2 Estimation of energy requirements

Instant-pounded yam flours were produced by cooking method described by (Olorunda et al.1977), steaming method as described by (Aworh, 2010), and wet milling method, (Ofi 2005). The processes were peeling, washing; slicing, cooking for 25 min, drying at 60 ^{o}C, milling using hammer mill and packaging for the first method, while steaming (5minutes) and wet milling of washed yam slices was employed as replacements for cooking in the second and third methods respectively. Energy requirements for all unit operations were estimated by substituting the obtained data in tables 1, 2 and 3 for cooking, steaming and wet milling methods respectively into equations 1 to 7.

Peeling $E_P = [0.68N_pT_p]$ (1)

Washin g $E_w= [0.68N_wT_w]$ (2)

Slicing $E_S = [0.68\times N_ST_S]$ (3)

Cooking $E_c = [X_c K_c + (0.68N_ct_c)]$ (4)

Drying $E_d=[X_d K_d + [0.75+ N_dT_d]$, (5)

Milling $E_m=Y_mC_{m +} (Z_mP_mT_m +0.75N_mT_{m)}]$ (6)

Packaging $E_K= Y_kC_{k +} (Z_KP_KT_K+0.075N_KT_K)$ (7)

Total energy $E_T = E_P+E_S+E_C+E_D+E_M+E_K$. (8)

Energy intensity $E= E_P+E_S+E_C+E_D+E_M+E_K /1000Kg$ (9)

i,.e Energy intensity = Total energy /quantity, Where E is quantity of energy (MJ)

0.75 MJ/h is the average power input by a male labour, (Abubakar et al., 2010)
0.68 MJ/h is the average power input by a female labour (Abubakar et al., 2010)
N is the number of persons involve in an operation.
T is the time to complete the operation (h)
K is the caloric value of kerosene (MJ/L)
X is the quantity of kerosene used (L)
C is the caloric value of diesel (J/L)
Y is the quantity of diesel used (L)
Z is the power factor of the machine
P is quantity of electrical energy used (KWh).

Subscripts ($_{P,\ W,\ S,C,D,M,K,}$) were used to indicate the particular unit operation, for which energy estimated was carried out, i.e. peeling, washing, slicing, cooking, milling, packaging respectively.

Table 1. Data used in energy requirement estimation for cooking method **

Operations/ Requirement	Peeling	Washing	Slicing	Cooking	Drying	Milling	Packaging
Fuel (L)	-	-	-	52±1.4	142±1.4	12 ±1.7	5.5±0.7
Caloric value (MJ/L)	-	-	-	31±0.00	31±0.00	36.0±0.0	36.0±0.0
Electricity(KW)	-	-	-	-	-	0.3±0.0	0.3±0.00
Time (h)	0.9±0.1	0.5±0.0	1.3±0.5	0.6±0.1	17.0±1.4	1.0±0.0	1.0±0.0
Labour (Size)	9.0±1.4	9.0±1.4	9.0±1.4	5.0±1.4	4.0±0.0	4.0±0.0	2.0±0.0
Labour (gender)	Female	Female	Female	Female	Male	Male	Male

** Mean of nine replicates

Table 2. Data used in energy requirement estimation for steaming method **

Operations/ Requirement	Peeling	Washing	Slicing	Steaming	Drying	Milling	Packaging
Fuel (L)	-	-	-	24±1.2	175.5±1.4	13.5 ±1.4	5.5±0.7
Caloric value (MJ/L)	-	-	-	36.0±0.0	31±0.00	36.0±0.0	36.0±0.0
Electricity(KW)	-	-	-	0.3±0.0	-	0.3±0.0	0.3±0.00
Time (h)	0.9±0.1	0.5±0.0	1.3±0.5	0.33	21.0±1.4	1.5.±0.0	1.0±0.0
Labour (Size)	9.0±1.4	9.0±1.4	9.0±1.4	5.0±0.0	4.0±0.0	4.0±0.0	2.0±0.0
Labour (gender)	Female	Female	Female	Female	Male	Male	Male

** Mean of nine replicates

Table 3. Data used in energy requirement estimation for wet-milling method **

Operations/ Requirement	Peeling	Washing	Slicing	Wet-milling	Drying	Milling	Packaging
Fuel (L)	-	-	-	15±1.2	105.5±1.4	6.5 ±1.4	5.5±0.7
Caloric value (MJ/L)	-	-	-	36.0±0.0	31±0.00	36.0±0.0	36.0±0.0
Electricity(KW)	-	-	-	0.3±0.0	-	0.3±0.0	0.3±0.00
Time (h)	0.9±0.1	0.5±0.0	1.3±0.5	0.75±0.0	9.0±1.4	0.30.±0.0	1.0±0.0
Labour (Size)	9.0±1.4	9.0±1.4	9.0±1.4	5.0±0.0	4.0±0.0	4.0±0.0	2.0±0.0
Labour (gender)	Female	Female	Female	Male	Male	Male	Male

** Mean of nine replicates

3.0 Results and Discussion

3.1 Energy requirements

Table 4 shows energy distribution pattern of the three methods of instant-pounded yam production. Peeling, washing, slicing and packaging, with respective energy requirements of 5.51MJ, 3.06MJ, 7.96MJ and 200.79MJ were constant for the three methods. However, cooking, drying and dry-milling energy demands for the cooking method were 1614.0MJ, 4453.0MJ, 435.79MJ, respectively, and the total energy demand was estimated as 6720.15MJ. Using the steaming method, steaming, drying, milling and total energy requirements were 745.12MJ, 5481.0 MJ, 491.04MJ, and 6934.48MJ respectively. While in wet-milling method, respective energy requirement were estimated as 543.40MJ, 3290.0MJ, 245.84MJ and 4296.56MJ for wet milling, drying, dry milling and total. It follows that 6720.15MJ, 6934.48MJ, and 4296.56MJ, an equivalent of 6.7 MJ/kg, 6.9 MJ/kg and 4.3 MJ/kg respectively were utilized for cooking, steaming and wet-milling methods of instant-pounded yam flour production. Total energy used was not significantly different ($p>0.05$) between cooking and steaming methods while wet milling differ significantly ($p<0.05$). Wet milling recorded least energy intensity. Omission of unnecessary unit operations can contribute significantly to energy conservation potential of a particular processing technology (Muhammed, 2009). Wet milling method does not defect most of the starch granules, which is of vital point in good-pounded yam (Ofi 2005, Aworh, 2010). The energy expended, in each method was higher than 0.316 MJ/kg reported for production of cassava flour (Jekayinfa and Olajide, 2007). The differences may be traced to the crops physiology and technology involved.

Energy demand for dry milling in the three methods vary significantly ($p<0.05$).This may be attributed to initial treatment (cooking, steaming, wet milling) which has affected the hardness property of the sample in varied proportion. Percentage proportion of energy used showed that 0.08, 0.05, 0.12, 24.02, 66.26, 6.50 and 2.99% of the total energy input were consumed by peeling, washing, slicing, cooking, drying, milling and packaging operations respectively in cooking method. Percentage distribution of energy used in steaming method was 0.08, 0.04, 0.11, 10.75, 79.04, 7.08, 2.90% for peeling, washing, slicing, steaming, drying, milling and packaging operations respectively. While for wet milling method, 0.13, 0.07, 0.19, 12.65, 76.57, 5.72 and 4.67% energy was used for peeling, washing, slicing, wet- milling, drying, milling and packaging operations respectively. Drying consumed more than half of the total energy requirements in each method. The results showed that drying operation consumed 5481.0 MJ (66.26%), 4453.0 MJ (79.04%) and 3290.0MJ (76.57%) in steaming, cooking and wet milling method respectively. Similar observation was reported on production of milk powder (Ramirez et al., 2006). Drying as a unit operation consumes large proportion of energy in food processing (Singh, 1986). The specific energy consumption by air-drying systems varies significantly with operating parameters (Sarsavadia, 2007). These operating parameters include air velocity, temperature, relative humidity, fraction of air recycled and surface area of drying material. Washing consumed least energy (3.06 MJ) and was uniform for all the methods.

Table 4.0: Energy requirements of the three methods

Unit Operation	Cooking Method (MJ)	%energy utilization	Steaming Method (MJ)	%energy utilization	Wet-milling Method (MJ)	%energy utilization
Peeling	5.51	0.08	5.51	0.08	5.51	0.13
Washing	3.06	0.05	3.06	0.04	3.06	0.07
Slicing	7.96	0.12	7.96	0.11	7.96	0.19
Cooking	1614	24.02	-	-	-	-
Steaming	-	-	745.12	10.75	-	-
Wet-milling	-	-	-	-	543.40	12.65
Drying	4453.0	66.26	5481.0	79.04	3290.0	76.57
Dry- milling	435.79	6.50	491.04	7.08	245.84	5.72
Packaging	200.79	2.99	200.79	2.90	200.79	4.67
Total	6720.15	100.	6934.48	100	4296.56	100

4.0 Conclusions

Findings of the research showed that energy usage in instant-pounded yam flour production depends on unit operations and processing technology. Energy required for processing 1000 kg of yam to instant-pounded yam flour using cooking method, steaming method and wet-milling methods were 6720.15MJ, 6934.48MJ and 4296.56MJ respectively, equivalent to 6.7 MJ/kg, 6.9 MJ/kg and 4.3 MJ/kg respectively. Energy intensity for peeling, washing, slicing and packaging were 0.0055 MJ, 0.003 MJ, 0.0076 MJ and 0.2 MJ respectively, and are the same for all the methods studied. Drying consumed more than half of the total energy requirements in each method; cooking (66.26%), steaming (79.04%) and wet-milling methods (76.57%). Using energy demand as criterion, wet- milling method is recommended. In addition, quality and acceptability of the product should be further investigated.

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