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# Elucidating Energy Requirements in Alternative Methods of Robo Production

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## Abstract

**Purpose:** This study was designed to elucidate the energy-utilization patterns for five methods of robo production. **Methods:** Robo (fried melon cake) was produced using five different methods, and the energy used for each unit operation was calculated using standard equations. The sensory attributes of the products were determined by panelists. Data were analyzed using descriptive analysis and analysis of variance at $p < 0.05$. **Results:** The energy demands for processing 2.84 kg of melon seed into robo (fried melon cake) using processes 1 (traditional method), 2, 3, 4, and 5 (improved methods) were 50,599.5, 21,793.6, 20,379.7, 21,842.9, and 20,429.3 kJ, respectively. These are equivalent to energy intensities of 1,7816.7, 7,673.8, 7,175.9, 7,691.2, and 7,193.4 kJ/kg, respectively. For the traditional process, the frying operation consumed the highest energy (21,412.0 kJ), and the mixing operation consumed the lowest energy (675.0 kJ). For the semi-mechanized processes, the molding operation consumed the highest energy (6,120.0 kJ), and the dry milling consumed the lowest energy (14.4 kJ). **Conclusions:** The energy-consumption patterns were functions of the type of unit operation, the technology involved in the operations, and the size of the equipment used in the whole processing operation. Robo produced via the milling of dried melon seed before oil expression was rated highest with regard to the aroma and taste quality, as well as the overall acceptability of the sensory evaluation, and required the lowest energy consumption. Full mechanization of the process line has potential for further reduction of the energy demand.

**Keywords:** Energy consumption, Energy intensity, Melon seed, Processing methods, Robo

## Introduction

The global food sector is dependent on energy inputs. For obvious reasons, energy is regarded as the prime mover of any economy and the engine of growth around which all sectors of the economy revolve. Thus, it is imperative that its development, management, and improvement have predetermined plans and strategies that are capable of driving the economy towards a sure path of sustainable development (Jesuleye, 1999). The food and agricultural sectors in developing countries have been significantly transformed with regard to the way food is produced, processed, marketed, and consumed (Swinnen and Maertens, 2007). Consumers have been responding to changes in the quality of food intake and are becoming increasingly conscious regarding nutrition, health, and food safety issues (Umali-Deininger and Sur, 2007). The food industry is one sector of agriculture that consumes energy. The energy consumed is based on the stages of production, starting from the planting stage to the distribution stage. However, energy can be applied in various stages, such as land preparation, planting, chemical application, harvesting, primary processing, secondary processing, preservation, packaging, and distribution. Effective energy utilization and energy source management in processing facilities are desirable for the reduction of processing costs, conservation of non-renewable energy resources, and reduction of environmental impact (Akinoso et al., 2013).

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The introduction of mechanization to achieve a high processing capacity has caused the food industry to depend more heavily on energy obtained from petroleum products. Before the mid-1970s, in many industrial nations, the low price of fuel discouraged emphasis on energy conservation in the design and operation of food-processing equipment (Akinoso et al., 2013). Industries generally use various energy sources, such as oil, gas, coal, solar, nuclear, wood-fuel, and electricity, in the process of obtaining the final product. The food industry requires energy for a variety of equipment, such as gas-fired ovens, dryers, steam boilers, electric motors, refrigeration equipment, heating systems, and ventilation and air-conditioning systems (Aderemi et al., 2009).

The egusi melon belongs to the family Cucurbitaceae, which consists of cucumber, watermelon, and pumpkin. It is a relative of watermelon. Its seeds are utilized directly for human consumption. Its seed type, bitter fleshy pulp, and pulp color differentiate it from watermelon (Adeniran, 1994). Melons (*Colyncithus citrulus* Lanactus) are major food crops with several varieties and serve as a major food source (Mabalaha et al., 2007). Cucurbits are among the most economically important vegetable crops worldwide and are grown in both temperate and tropical regions (Abaelu, 1979). Melon seed kernels are major soup ingredients and are used as a thickener and flavor component of soups. Melon seeds are less expensive and are widely distributed. They can contribute substantially to a balanced diet (Fokou et al., 2004). Their oil content is comparable to those of other oil plants. The egusi melon contains water, vitamins, and a fair amount of minerals, such as P, K, Mg, Ca, Zn, and Fe (Omidiji, 1977). The seeds—popularly called “egusi”—contain approximately 53% oil, 28% protein, and other important mineral nutrients (Abaelu, 1979). They are consumed in “egusi soup,” melon ball snacks (robo) and “ogiri” (a fermented condiment) (Ayo Odunfa, 1981). Melon seeds contain a high amount of unsaturated fatty acid and linoleic acid. The oil expressed from the seeds is used for dietary purposes (Ajibola et al., 1990), and the residual cake is fried and consumed as a snack.

Generally, the production of fried melon cake (robo) has remained a traditional family art in homes with rudimentary utensils. The traditional process consists of roasting, sorting, cleaning, milling, kneading/oil expression, molding, frying, and packaging. In the production of fried melon cake, the shelled melon seed is subjected to roasting at a temperature of 100 °C for approximately 9 min. Typically, the roasting is performed in batches, and the traditional process employs wood, which makes the roasted seed less uniform in color. The roasted melon seeds are then carefully sorted and subjected to winnowing to remove debris. The roasted egusi melon is dry-milled using a manual attrition mill. This is also done in batches, and it takes time and energy depending on the quantity of melon to be milled. The kneading process is one of the unit operations that determines the quality of the fried melon cake. However, it is tedious, laborious, and time-consuming, and its failure can lead to wastage of the melon seeds, especially if the seeds are not well- defatted. To minimize the time and energy consumption, and for successful separation of the melon oil and melon cake, a mechanical oil press is used, which reduces the time and energy requirements. As a defatted melon cake must be fried in order to produce a fried melon cake, a mechanical method was introduced for expressing the oil from the seed.

The popularity of robo as a snack is declining owing to its hardness in texture, which makes it difficult to consume for children and adolescents. Additionally, most of the unit operations involved in robo production are performed manually, making them laborious, energy-consuming, and time consuming. Thus, there is a need to devise methods for improving the robo quality and mechanizing the production line. With respect to specific commodities, various studies have been conducted on the energy-consumption patterns in the processing operations of crops, such as sunflower oil (Farsaie and Singh, 1985), palm kernels (Jekayinfa and Bamgboye, 2007), cashews (Mohod et al., 2010), rice (Roy et al., 2008), cassava (Jekayinfa and Olajide, 2007), flaxseed (Zheng et al., 2005), and barley (Afzal et al., 1999). There is a dearth of information on the energy requirements in the production of fried melon cake. Research on the energy-demand pattern in robo (fried melon cake) production provides bases for efficient energy utilization and conservation, reducing the production cost. Therefore, this study was designed to elucidate the energy-utilization patterns for five methods of robo production.

## Materials and Methods

### Processes of robo production

Robo (fried melon cake) was produced using the traditional method (process 1), which involves the following unit operations: roasting, sorting and cleaning, wet milling, dry milling, kneading, molding, frying, and packaging (Fig. 1). For the production of the fried melon cake, 2.84 kg of shelled melon seed was used. The unit operations started with the roasting process, which involves subjecting the melon seed to heat treatment in a pan at a temperature of 100°C for approximately 9 min. This was done to develop a new flavor for the melon seed and ease the oil-expression process for the melon-cake production. After roasting, the next unit operation was sorting and cleaning, which involves the removal of dirt and foreign materials from the melon seed prior to further processing. This was performed by using the wind to winnow the seed. The next unit operation was milling. The roasted melon seed was milled using a manual attrition milling machine, taking the form of a paste/slurry. A mixture of spices and seasonings (dry pepper, onions, salts, bouillon cubes, and dry fish) was wet-milled using an electrical attrition mill. The milled melon seed was then kneaded for 45 min with the addition of hot water at intervals before the spices and seasoning were mixed with it. The kneading process continued and oil was expressed for another 15 min. The cake was molded using the tip of the finger for 2 h. The molded balls were fried, air-cool, and packed.

A hydraulic screw press for oil expression was employed to improve the production method. Four different processes were developed and tested: process 2, milling of roasted melon seed before oil expression (Fig. 2); process 3, milling of dried melon seed before oil expression (Fig. 3); process 4, milling of roasted melon seed after oil expression (Fig. 4); and process 5, milling of dried melon seed after oil expression (Fig. 5). Instead of using a firewood stove for roasting, as is done in the traditional method, processes 2 and 4 used an electric stove and a heated pan, respectively. In this case, a controlled temperature was achieved, and a large quantity of the seed was roasted at one time. Spices were dry-milled using an electrical blender, unlike the wet milling of the traditional method, which employs an attrition mill. The same ingredients were used for the five methods.

The sensory attributes of the robo were determined via an acceptance test. Each sample was rated using a nine-point hedonic scale with regard to five attributes (aroma, taste, texture, appearance, and overall acceptability). The scale ratings were as follows: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike moderately, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely. Coded samples were served to 25 trained pane-

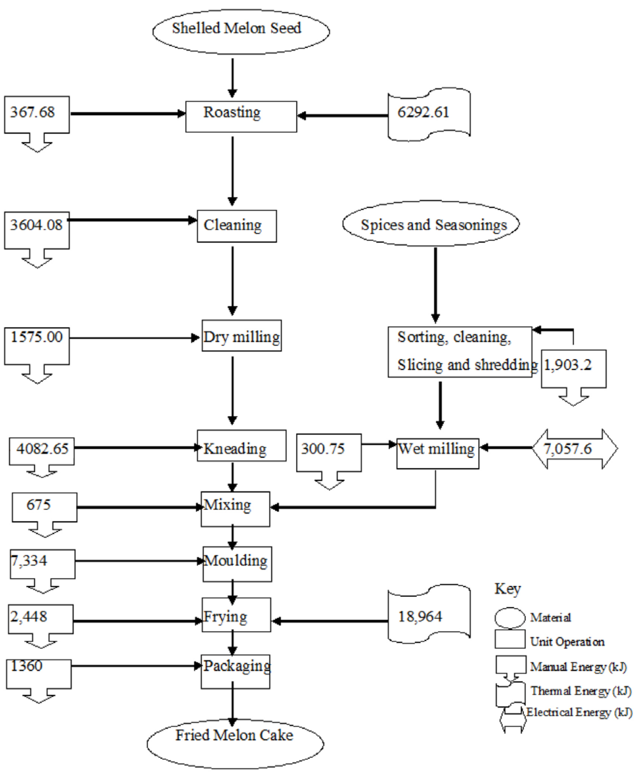


**Figure 1.** Energy-flow diagram for process 1 (traditional method).

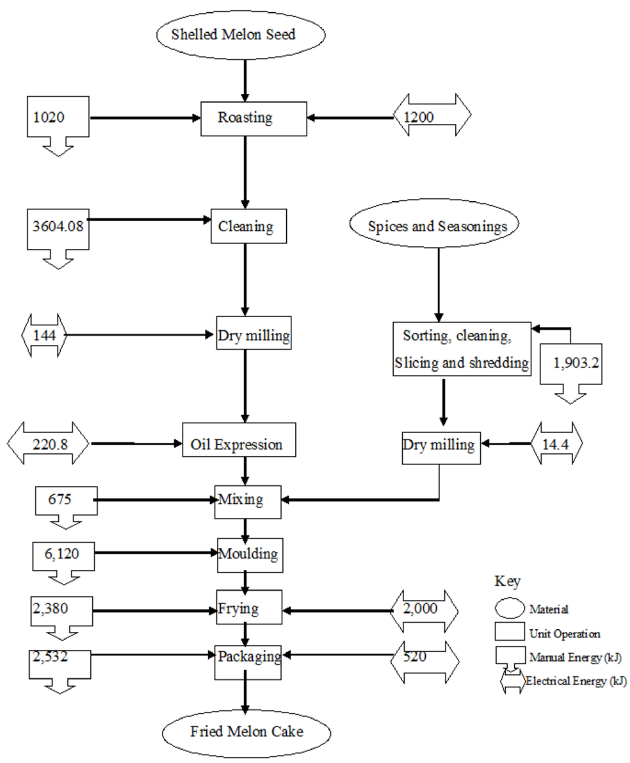


**Figure 2.** Energy-flow diagram for process 2.

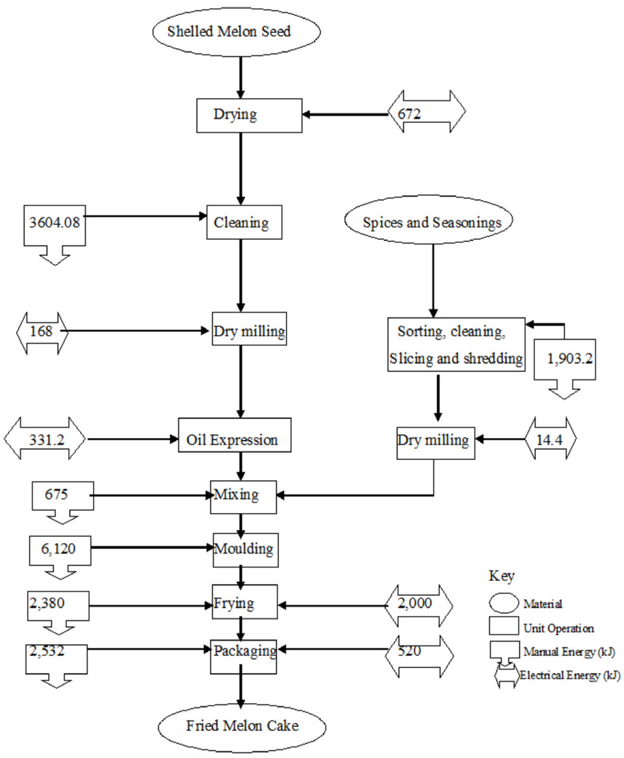


**Figure 3.** Energy-flow diagram for process 3.

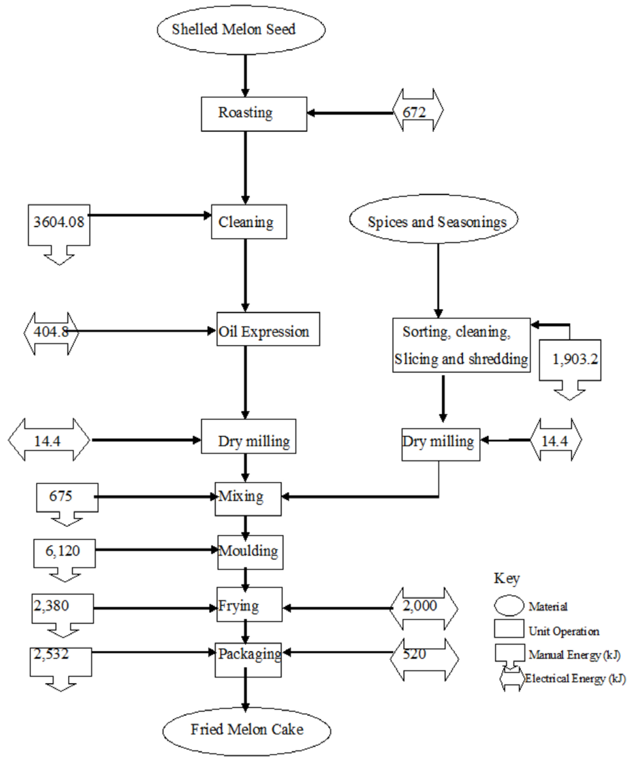


**Figure 5.** Energy-flow diagram for process 5.

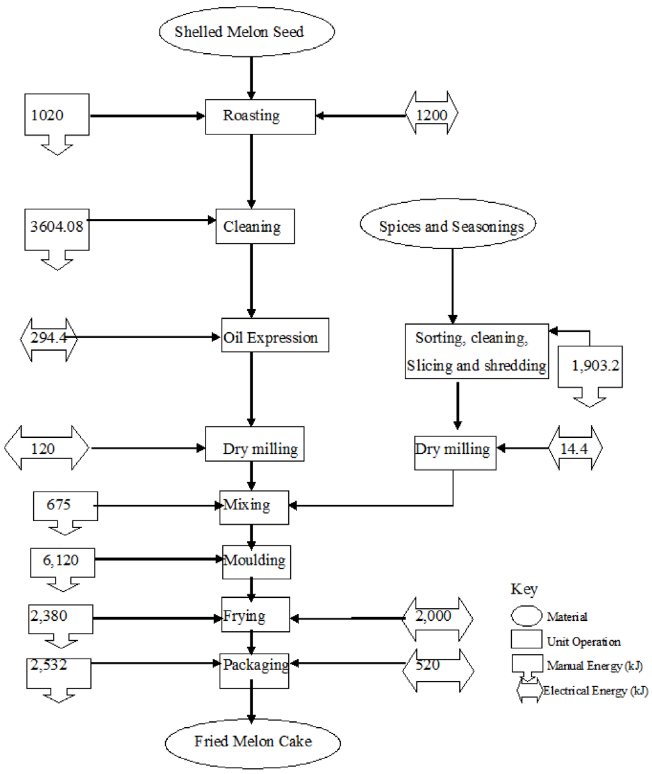


**Figure 4.** Energy-flow diagram for process 4.

lists, positioned in partitioned booths. The aroma, taste, texture, and overall acceptability of the robo were evaluated under amber light, and the appearance was evaluated under bright illumination. Samples receiving an overall quality score of $\geq 6$ were considered acceptable.

## Quantification of energy input in robo production

The melon seed (2.84 kg) was processed into robo in a laboratory, as described above. The energy inputs for the production were determined via direct measurement and data collection of the applicable parameters in each unit operation during production (Table 1), and by fixing the data to standard equations (Equations 1-6). The procedures were repeated three times, and the mean data were recorded. A descriptive analysis was performed on the data obtained, as well as an analysis of variance at a 5% significance level.

$$E_p = KPt \tag{1}$$

$$E_t = C_f W \tag{2}$$

$$E_m = MNt \tag{3}$$

$$E_f = FNt \tag{4}$$

**Table 1.** Measured parameters for evaluating energy-consumption pattern

| Unit Operation | Required Parameters | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Roasting | Number of person | 1 | 1 | NA | 1 | NA |
| | Fuel consumed (kg) | 0.359±0.01 | NA | NA | NA | NA |
| | Electric stove power (kW) | NA | 1 | NA | 1 | NA |
| | Time (s) | 551±28 | 1500±35 | NA | 1482±56 | NA |
| Drying | Number of person | NA | NA | 1 | NA | 1 |
| | Time (s) | NA | NA | 600±42 | NA | 604±18 |
| | Rated power (kW) | NA | NA | 2.8 | NA | 2.8 |
| Cleaning | Number of person | 3 | 3 | 3 | 3 | 3 |
| | Time (s) | 1512±93 | 1500±54 | 1492±39 | 1502±24 | 1499±68 |
| Sorting | Number of Persons | 3 | 3 | 3 | 3 | 3 |
| | Time (s) | 933±25 | 600±61 | 607±42 | 568±50 | 613±14 |
| Oil Expression | Time (s) | NA | NA | NA | 60±13 | 80±07 |
| | Number of persons | NA | NA | NA | 2 | 1 |
| | Rated power (kW) | NA | NA | NA | 4.6 | 4.6 |
| Dry Milling | Time (s) | 2100±29 | 441±37 | 460±54 | 401±42 | 300±41 |
| | Number of persons | 1 | 2 | 2 | 2 | 2 |
| | Rated power (kW) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Wet Milling | Time (s) | 401±26 | 180±18 | 171±32 | 187±40 | 176±18 |
| | Number of persons | 1 | 1 | 1 | 1 | 1 |
| | Rated power (kW) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Kneading | Time (s) | 2855±91 | NA | NA | NA | NA |
| | Number of persons | 2 | NA | NA | NA | NA |
| Oil Expression | Time (s) | NA | 60±09 | 70±11 | NA | NA |
| | Number of persons | NA | 2 | 1 | NA | NA |
| | Rated power (kW) | NA | 4.6 | 4.6 | NA | NA |
| Mixing | Time (s) | 900±13 | 586±10 | 600±46 | 612±33 | 607±34 |
| | Number of persons | 1 | 1 | 1 | 1 | 1 |
| Molding | Time (s) | 3600±45 | 3010±76 | 3022±28 | 3002±64 | 3000±39 |
| | Number of persons | 3 | 3 | 3 | 3 | 3 |
| Frying | Time (s) | 3600±67 | 2500±43 | 2508±53 | 3510±4 | 3500±18 |
| | Number of persons | 1 | 1 | 1 | 1 | 1 |
| | Rated power (kW) | 1 | 1 | 1 | 1 | 1 |
| Packaging | Time (s) | 1360±54 | 1207±63 | 1960±26 | 1200±84 | 1873±36 |
| | Number of persons | 3 | 2 | 2 | 2 | 2 |
| | Rated power (kW) | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

"NA" means "not applicable"

$$T_e = \sum E_u \tag{5}$$

$$E_{in} = \sum E_u / Q \tag{6}$$

Here, $E_p$ is the electrical energy consumed (kWh); $P$ is the rated power of the motor (kW); $t$ is the operation time (h), $K$ = 0.8 is the power factor; $E_t$ is the thermal energy consumed (MJ); $C_f$ is the calorific value of fuel used (MJ/kg), which is 17.51 and 43.1 MJ/kg for wood and kerosene, respectively; $W$ is the quantity of fuel used (kg); $M$ is the average power input by a male laborer (0.75 MJ/h) (Abubakar et al., 2010); $F$ is the average power input by a female laborer (0.68 MJ/h) (Abubakar et al., 2010); $T_e$ is the total energy consumed (MJ); and $E_{in}$ is the energy intensity (MJ/kg).

# Results and Discussion

## Energy demand for process 1

The total energy for converting 2.84 kg of melon seed into robo (fried melon cake) using the traditional process was 50,599.5 kJ, with energy intensity of 17,816.7 kJ/kg, consisting of 49.91% (25,256.6 kJ) thermal energy, 48.69% (24,637.08 kJ) manual energy, and 1.39% (706 kJ) electrical energy (Table 2). The expended energy intensities were lower than 2,950,000 kJ/kg for batch-process bread making (Akinoso and Ganiu, 2011). The mixing and frying processes were the least and most energy-intensive unit operations, with percentages of 1% (675 kJ/kg) and 42% (21,412 kJ/kg), respectively. A similar observation was reported by Akinoso and Ganiu (2011) during bread making. The frying process had the highest energy input because it combined two energy sources (thermal and manual energy inputs). In this process, the thermal energy was supplied by a kerosene stove having a low energy-conversion efficiency. The wet milling of spices (1.99%) and the mixing (1.33%) processes accounted for 3.32% of the total energy, while the other unit operations—including roasting, cleaning, sorting, milling, molding, frying, and packaging—accounted for 51% of the total energy.

## Energy demand for process 2

In this process, the total energy input was estimated to be 21,793.6 kJ, as shown in Table 2, and the energy intensity was 7,673.8 kJ/kg. The moulding process was the most energy-intensive operation, with a total energy of 6,120 kJ, corresponding to 28% of the total energy input. This is because three persons were involved for a long period of time. According to Jekayinfa and Bamgboye (2007), the energy demand in food production is proportional to the quantity of raw materials and the time taken for the production. Other unit operations with a low energy input of approximately 2% included oil expression, melon milling, and the dry milling of spices. Oil expression has a low energy demand compared with the kneading process because the time required for oil expression using a hydraulic press was drastically reduced from 45 min in process 1 to <2 min in process 2. This process utilized manual and electrical energy. The manual energy was estimated to be 17,694.4 kJ, corresponding to 81% of the total energy input, while the total electrical energy was estimated as 4,099.20 kJ, corresponding to 19% of the total energy.

## Energy demand for process 3

The estimated energy expended was 20,379.7 kJ, while the energy intensity was 7,175.9 kJ/kg (Table 2). The unit operation of moulding consumed 6,120 kJ, corresponding

**Table 2.** Comparison of total energy between traditional process and semi-mechanized processes

| | Process 1 | | Process 2 | | Process 3 | | Process 4 | | Process 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit Operation | kJ | % | kJ | % | kJ | % | kJ | % | kJ | % |
| Roasting | 6667.29 | 13.17 | 2220 | 10.19 | - | - | 2020 | 10.16 | - | - |
| Drying | - | - | - | - | 672 | 3.30 | - | | 672 | 3.29 |
| Cleaning | 3064.08 | 6.06 | 3064.08 | 14.06 | 3064.08 | 15.03 | 3064.08 | 14.03 | 3064.08 | 15.00 |
| Sorting | 1903.32 | 3.76 | 1903.32 | 8.73 | 1903 | 9.34 | 1903 | 8.71 | 1903 | 9.32 |
| Kneading | 4082.65 | 8.07 | - | - | - | - | - | - | - | - |
| Oil expression | - | - | 220.8 | 1.01 | 331.2 | 1.63 | 294.4 | 1.35 | 404.48 | 1.98 |
| Wet milling of spices | 1006.51 | 1.99 | - | - | - | - | - | - | - | - |
| Dry milling of spices | - | - | 14.4 | 0.06 | 14.4 | 0.07 | 14.4 | 0.07 | 14.4 | 0.07 |
| Milling of melon | 1575 | 3.11 | 144 | 0.66 | 168 | 0.82 | 120 | 0.55 | 144 | 0.70 |
| Mixing | 675 | 1.33 | 675 | 3.1 | 675 | 3.31 | 675 | 3.09 | 675 | 3.30 |
| Molding | 7344 | 14.51 | 6120 | 28.08 | 6120 | 30.03 | 6120 | 28.02 | 6120 | 29.96 |
| Frying | 21412 | 42.31 | 4380 | 20.1 | 4380 | 21.49 | 4380 | 20.05 | 4380 | 21.44 |
| Packaging | 2869.6 | 5.67 | 3052 | 14 | 3052 | 14.98 | 3052 | 13.97 | 3052 | 14.94 |
| Total[§] | 50599.5[c] | 100 | 21793.6[b] | 100 | 20379.7[a] | 100 | 21842.9[b] | 100 | 20429.3[a] | 100.00 |

[§]Total energies with the same superscript in a row are not significantly different at $p < 0.05$.

to 30% of the total energy input. The moulding operation had the highest energy input owing to the period of time involved. Other unit operations with an energy input of 3% or lower included oil expression, dry milling of the spices and melon seed, and mixing. Manual and electrical energy were used in this method of robo production. The manual energy consumed was 16,674.40 kJ, corresponding to 81.00% of the total energy input, while the total electrical energy consumed was estimated to be 3,705.60 kJ, corresponding to 18.07% of the total energy. The involvement of manual labor in all unit operations accounted for this energy pattern.

## Energy demand for process 4

The cumulative energy used and energy intensity were 21,842.9 kJ and 7,691.2 kJ/kg, respectively. The molding process had the highest energy demand of 6,120 kJ, corresponding to 28% of the total energy input. Other unit operations with an energy input of 3% or lower were oil expression, dry milling of the melon seed and spices, and mixing. Only manual (17,694.08 kJ, 73%) and electrical (3,948.80 kJ, 27%) energy were used in this process. The observed trend warrants a reduction in the use of manual labor.

## Energy demand for process 5

The total energy used in this method of production was estimated as 20,429.3 kJ (Table 2), yielding an energy intensity of 7,193.4 kJ/kg. The molding process was the most energy-intensive, with a total energy of 6,120 kJ, corresponding to 30% of the total energy input. Oil expression, dry milling of the spices and melon seed, and mixing each utilized <3%. The short duration of the use of machines for these operations accounted for the lower energy utilization. Manual energy of 16,674.08 kJ (81.61%) and electrical energy of 3,754.88 kJ (18.38%) were used. The application of manual labor consumed time and energy if quantified.

## Comparison of energy-consumption patterns of processes

The total energy demand for process 1 (traditional method), process 2 (milling of roasted melon seed before oil expression), process 3 (milling of dried melon seed before oil expression), process 4 (milling of roasted melon seed after oil expression), and process 5 (milling of dried melon seed after oil expression) was 50,599.5, 21,793.6, 20,379.7, 21,842.9, and 20,429.3 kJ, respectively (Table 2). It is evident that using a machine to express oil considerably reduces the energy consumption. The energy consumed when the hydraulic press was used was 14.4 kJ, while the same objective was achieved through a combination of kneading (1,575 kJ), wet milling (1,006.51 kJ), and dry milling (4,082.65 kJ), which had a total energy consumption of 6,664.16 kJ. Additionally the energy inputs for roasting (6,667 kJ) and frying (21,412 kJ) were higher than the corresponding values of 2,220 and 21,412 kJ in other processes where a machine was used. The length of time and amount of labor may account for this result. The drying process consumed less energy (672 kJ) than roasting (2,220-6,667 kJ), which is attributed to the low energy efficiency of the burner used for roasting. The energy efficiency improved with better utilization of the installed production capacity (Mohod et al., 2010)

The same quantity of energy was used for mixing and the preliminary of operations of cleaning, sorting, peeling, slicing, and shredding. Roasting accounted for 13.17% of the total energy in process 1, which decreased to 10.19% and 10.16% of the total energy in processes 2 and 4, respectively. The variation in the energy demand for this operation may be associated with the type of stove. The types of heat source, cooking device, and appliances were also important factors affecting the energy requirements (Akinoso and Oladeji, 2017). The total energy used in the drying process for processes 3 and 5 was 3.3% and 3.29%, respectively. The percentage of the total energy consumed during the cleaning and sorting, peeling, slicing, and shredding in process 1 (3.76%) was considerably lower than those in processes 2, 4 and 3, 5, in which their values were of the same range (8.73-9.34%). The manual kneading process accounted for 8.07% of the total energy consumed in process 1, whereas the mechanical oil expression accounted for <2% in each mechanized process. The kneading process consumed a longer period of time (2,855 s) in the traditional process; the maximum time consumed by the mechanical press was 80 s.

The spice wet-milling energy consumption was higher than that for dry spice milling. This observation is contrary to the findings of Akinoso et al. (2013) that wet milling consumed less energy than dry milling. This discrepancy is attributed to the type of size-reduction machine used. Although electrical energy was used in both cases, the electrical attrition mill had a higher rated power output than the electrical blender used for dry spice milling. McCabe et al. (2005) reported that size reduction is one of the least energy-efficient unit operations. This accounts for the higher energy demand of the attrition mill. The milling of the melon seed in process 1 accounted for 3.11% (1,575 kJ) of the total energy, whereas this percentage for the other processes was <1% (144-168 kJ). The unit operation of frying in process 1 accounted for the highest amount of energy consumed: 42% (21,412 kJ). This is attributed to the low efficiency of the kerosene stove, which provided the thermal energy used for the operation. A similar observation was reported by Akinoso and Kasali (2012) during the garification of gari. Molding—a manual operation—accounted for approximately 30% of the energy consumed in processes 2, 3, 4, and 5. Although these processes have low power requirements, they are time-consuming. This observation calls for the development of a mechanical molder for robo production.

## Sensory characteristics of products

All the sensory attributes except for appearance (aroma, taste, texture, and overall acceptability) were similar among the processes (Table 3). According to the ratings, robo produced via the traditional method (process 1) exhibited the best texture, while process 2 (milling of roasted melon seed before oil expression) exhibited the best appearance. Considering a rating greater than or equal to 6 points as the benchmark for acceptability, processes 2 (milling of roasted melon seed before oil expression) and 5 (milling of dried melon seed after oil expression) failed the sensory-attribute test. Process 3 (milling of dried melon seed before oil expression) exhibited the best aroma and taste quality, as well as overall acceptability, in the sensory evaluation. This method also had the lowest energy demand (Table 4).

**Table 3.** Sensory attributes of products

| Process | Appearance | Aroma | Taste | Texture | Overall acceptability |
|---|---|---|---|---|---|
| 1 | $6.78^{b}$ | $6.28^{a}$ | $6.07^{a}$ | $6.35^{a}$ | $6.14^{a}$ |
| 2 | $5.42^{a}$ | $6.21^{a}$ | $6.35^{a}$ | $5.42^{a}$ | $5.85^{a}$ |
| 3 | $6.50^{ab}$ | $6.57^{a}$ | $6.78^{a}$ | $6.21^{a}$ | $6.35^{a}$ |
| 4 | $5.92^{ab}$ | $5.92^{a}$ | $6.14^{a}$ | $6.14^{a}$ | $6.28^{a}$ |
| 5 | $5.24^{a}$ | $5.57^{a}$ | $6.28^{a}$ | $5.57^{a}$ | $1.1^{a}$ |

Values with the same superscript in a column are not significantly different at $p < 0.05$.

## Conclusions

The energy demand for processing 2.84 kg of melon seed into robo (fried melon cake) using processes 1 (traditional method), 2, 3, 4, and 5 (improved methods) was 50,599.5, 21,793.6, 20,379.7, 21,842.9, and 20,429.3 kJ, respectively. The corresponding energy intensities were 17,816.7, 7,673.8, 7,175.9, 7,691.2, and 7,193.4 kJ/kg, respectively. The energy-consumption patterns were functions of the type of unit operation, the technology involved in the operations, and the size of the equipment used in the whole processing operation. Manual and thermal energy were the dominant energy sources. It was clearly shown that using machines in the unit operations involved in the production of robo—a snack produced from melon seed—saved time, removed drudgery, and conserved energy. A mechanical press for oil expression was suitable for satisfying the objective of manual kneading. The use of kerosene and firewood stoves for frying and roasting, respectively, wasted energy. All the sensory attributes except appearance (aroma, taste, texture, and overall acceptability) were similar among the processes. Adoption of process 3 (milling of dried melon seed before oil expression) is recommended, as it has the lowest energy demand and the best overall acceptability in the sensory evaluation. Full mechani-

**Table 4.** Comparative rating of sensory scores and energy demand

| Process | Sensory attributes | | Energy input | |
|---|---|---|---|---|
| | Overall acceptability | Rating in terms of high acceptability | Total (kJ) | Rating in terms of lowest energy demand |
| 1 | $6.14^{a}$ | 3rd | $50599.5^{c}$ | 5th |
| 2 | $5.85^{a}$ | 4th | $21793.6^{b}$ | 3rd |
| 3 | $6.35^{a}$ | 1st | $20379.7^{a}$ | 1st |
| 4 | $6.28^{a}$ | 2nd | $21842.9^{b}$ | 4th |
| 5 | $1.2^{a}$ | 5th | $20429.3^{a}$ | 2nd |

Values with the same superscript in a column are not significantly different at $p < 0.05$.

zation of the process line has the potential for further reduction of the energy demand.

## Conflict of Interest

The authors have no conflicting interests, financial or otherwise.

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