Ergonomic Evaluation of IAR Manually Operated Groundnut Roaster

1 INTRODUCTION

Oil extraction from groundnut seed is prominent among rural women in Nigeria. Roasting one of the first key steps employed prior to oil extraction is important as oil extracted from roasted groundnuts is preferred to oil from unroasted groundnut (Gokhan and Vural 2010). In roasting, food products are subjected to an irreversible structural and thermal changes, which is followed by a reduction of moisture content (Fellows 2000). Traditionally, women involved in roasting groundnuts use open pans over direct fire. Here, ash or sand is introduced into the pans to a certain level, heated first to a certain temperature before the groundnut seeds are introduced. Agitators are used to stir the seeds continuously until a fairly uniform roasting is achieved (Okaioyeto, 2012). This process of roasting is tedious and time consuming, which led to the development of industrial roasters, however, acquiring and maintain industrial roasters is capital intensive. To offset the difference between traditional and the industrial methods of groundnut roasting, the Institute of agricultural Research (IAR) came up the design of a manually (human power) operated groundnut roaster.

Agricultural systems everywhere in the world require human labour as an input. The extent of human labour required varies so also is the basic function of the labour force (Ali, 1986). Ergonomics is the study of the interaction that people tend to establish or able to establish with the other elements of the system where they carry out their daily jobs (Tosi, 2020). Ergonomics is concerned with improving a system by improving human machine interactions. The main aim of ergonomics is to fit the task to the individual rather than fitting the individual to the task (Fernandez, 1995). It takes account of the specific demands of the task with reference to the capacity of the workers to perform the task.

Fernandez, (1995) identified anthropometry, seat design, work place principles, manual material handling and cumulative trauma disorder as the key ergonomic issues that must be considered in order to reduce work-related injuries, improve productivity and improve the quality of life of workers. Ojolo et al. (2016) evaluated the ergonomic aspect of a cashew nut shelling machine. The study identified the need for good hand grip and comfortable sitting arrangement as some of the ergonomic factors to be addressed. To address these ergonomic issues (Ojolo et al., 2016), made some modification to the existing cashew nut cracking machine, in doing so they were able to reduce the postural discomfort from 96.1% to 15%, mean workload was also reduced from 65.9% to 50.2% when compared to the earlier version of the machine. In the same vein, systems can be improved by evaluating some aspects of ergonomics. These ergonomics aspects are widely used in setting ergonomic related problems, they include energy or nutritional status (nutrition), musculo-skeletal energy use, work posture, time, social conditions, information conditions, and machine interface (Wahyu and Tania, 2018).

A human- machine systems refers to all conditions where humans use, controls or supervises tools or machines (Peter and Henk, 2008). These systems are found in almost every technological domain, under different modes which includes among several others: direct control, intermittent control and supervisory controls. These modes usually involve a human and a machine coming together to perform a function which results in a form of output. In this case the human is part of the system which must be fully integrated into it at the design stage. Human requirements are therefore system requirements, rather than secondary considerations. Therefore, the objective of this research work is to carry out an ergonomic study using two female subjects on the developed machine.
2 MATERIALS AND METHODS

2.1 DESCRIPTION OF IAR MANUALLY OPERATED GROUNDNUT ROASTER

Figure 1 shows the isometric views of the manually operated groundnut roaster. The machine consists of two major parts i.e. the drum and the charcoal chamber. Other components include frame, chain and sprocket, fan and fan housing, shaft, ball bearing, charcoal tray, bolts and nuts. The basic factors of ergonomics of the roaster are given in Table 1.

i. **Frame**: This is the supporting structure of the machine was constructed with 0.508 mm angle iron. Each doubled for stability and strength. The dimensions are as follows height 900 mm, breath 860 mm and width 460 mm; total weights due to the frame is approximately 40 kg.

ii. **Drum**: The drum which serves as the groundnut containing chamber during roasting was constructed with a 1 mm mild steel sheet. 1 mm mild steel sheet was used due to its high thermal conductivity. The drum has a diameter of 400 mm and a length of 800 mm. one side of the drum was constructed with a meshed wire for smoke outlet, and to enable direct visualization of the groundnut seeds while roasting. A helical structure was constructed lying at the inside wall of the drum, this helix is to enable efficient mixing of the seed while roasting and for conveying the roasted seed after roasting to the outlet.

iii. **Chain and Sprocket**: Chain and sprocket were used instead of belt and pulley due to their higher transmission efficiency of up to 98%, more power transmission, low maintenance cost and can be used for both small and large centre distances. The bigger sprocket (42 teeth) is attached to the central shaft of the drum while the smaller sprocket (14 teeth) is attached to the fan shaft. This arrangement is to allow for higher fan rotation.

iv. **Fan**: An axial fan is used because it gives more output over centrifugal when the rotation is low. The fan has a diameter of 240 mm. The fan is equipped with housing for unidirectional flow of air.

v. **Charcoal Tray**: This is constructed with a 3 mm mild steel sheet. The sides of the tray were constructed with mesh wire to serve as air vent. A maximum of 20 kg of dried charcoal can be loaded into the tray.

| Table 1. Design parameters of the manually operated groundnut roaster (Okaiyeto, 2012) |
| Parameter                  | Dimension |
|--------------------------|-----------|
| Height (Handle), mm      | 929       |
| Rotating diameter (Handle), mm | 422      |
| Diameter (Grab), mm      | 12        |
| Drum weight, Kg          | 14.80     |
| Capacity, kg             | 20        |

2.2 OPERATIONAL PRINCIPLES OF THE MACHINE

The machine is operated using a human as the source of power. A normal human produce 300 to 400 watts of power continuously over some few minutes (Ozcanli, 2010). The charcoal tray is to be filled with charcoal and the charcoal ignited. Free-burning charcoal could reach a temperature of about 900°C (Michio et al., 2013). When fully ignited, groundnut seeds (Maximum 20kg) are then introduced into the drum through the loading opening. The drum is then rotated slowly approximately 24rev/min. the rotation should be either clockwise or anticlockwise. The rotation is continued with intermittently stoppage to check the roast level of the seeds. When fully roasted i.e. when the seed temperature reaches 150°C, the charcoal tray is moved away from the drum. Then open the discharge opening and then place a collector at the discharge side, continue the rotation in anticlockwise this is due to the configuration of a helical structure in the inner lining of the drum, which helps to hasten the discharge of the roasted seeds.

2.3 EXPERIMENTAL PROCEDURE

The following apparatus were used during the test operation; a stopwatch, a tachometer, weighing scale, shelled groundnut seeds (SAMNUT 11), charcoal, hand ergometer, stethoscope and two women. The experiment was based on ergonomic approach. This is to get a basis for improvement in the design of the machine for comfortability of operators.

The Subjects: The study was conducted in the department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria. Two subjects were involved in the study. The subjects were selected based on their experience in local roasting of groundnut seeds for oil extraction. Their experience in roasting groundnut seeds makes them to appreciate the comfort of using a roasting machine. The physical and mental states of the subjects were ascertained to be sound. Personal anthropometric details were obtained and the average tabulated in Table 2. Seven measurements described by (Ali, 1986) relevant to the manual roasting of groundnut were measured.
2.4 HAND ERGOMETER

Hand ergometer was used to calibrate the subjects. Heat beat was determined using a stethoscope. A 5kg weight was placed on the flywheel of the hand ergometer with the aid of a friction belt. Then subject A who have been in rest position for 1hr is made to rotate the flywheel via a crank handle. Heartbeat of the subject was taken before and after each operation. The difference between the applied weight and a scale reading gives frictional force imposed on the flywheel. Revolution of the flywheel is measured using a tachometer. The whole process was repeated three times for subject A and subject B using 10, 15, 20, 25, 30, 35 and 40kg weight, respectively. Work done is given by equation 1 as put forward by (Ali, 1986).

\[ W = 2\pi nr \quad \text{or} \quad W = Fr\theta \] (1)

Where \( \Theta \) is rotation of flywheel in radians, \( r \) is radius of flywheel and \( n \) is the revolution of the flywheel.

Table 3 shows the result of hand ergometer experiment.

2.5 MACHINE ERGONOMIC EVALUATION

Prior to the ergonomic evaluation of the machine, both subjects were placed on a rest mode for 1hr. The experiment was started when the charcoal was fully ignited. Heart rate of subject A was taken before 5kg of groundnut seeds were introduced into the drum. The drum was rotated afterward at an average 20 to 25 rpm. Heart rated was taken again when the groundnut seeds were introduced into the drum. Work rate was then determined for each of the subject using their respective calibration curve (Figure 4 and Figure 5). When operating the roaster, the operator remains in a standing posture while rotating the drum via the handle through his/her elbow joint. The handle height ranges from 1140mm maximum to 718mm minimum during operation.

Table 3 shows the result of hand ergometer experiment.

3 RESULTS AND DISCUSSIONS

3.1 ANTHROPOMETRIC DATA OF SUBJECTS A AND B

Table 2 shows the anthropometric data obtained from the two subjects. From table 2, the two subjects been females have 1040 and 1010 mm as their elbow height, this is close to the 929mm height of the handle. These will enable the operator to rotate the drum at ease without much bending from their standing position.

Table 2. Anthropometric data of the two subjects

| Data          | Subject A | Subject B |
|---------------|-----------|-----------|
| Age, yrs.     | 29        | 51        |
| Weight, kg    | 69        | 85        |
| Height, mm    | 1620      | 1650      |
| Arm reach, mm | 700       | 720       |
| Pelvic height, mm | 550   | 970       |
| Hand length, mm | 740    | 770       |
| Elbow height, mm | 1040  | 1010      |

Table 3 shows the result of the hand ergometer experiment conducted on subject A and subject B. During the experiment a 15 minute rest period was observed after every run. For subject A, final heart beat increased gradually from 77 b/m to 106 b/m while that of subject B ranged from 79 b/m to 107 b/m. Work rate for subject A increased steadily from 450.9 J/m to 4167.7 J/m while subject B work rate ranged from 511.1 to 4794.5. Difference in heart rate is because of cardio dynamic differences between exercising and the lungs of the subjects (Drescher et al. 2017).

Figures 2 and 3 shows the calibration curve of the two subjects. The figures show the relationship between heart rate and work rate as it applies to an individual. Variation in the curves indicates a difference in some physical and physiological variables among the subjects.

3.2 CALIBRATION OF SUBJECT A AND B

Table 3 shows the result of the hand ergometer experiment conducted on subject A and subject B, during the experiment a 15 minute rest period was observed after

3.3 WORK RATE OF SUBJECTS DURING ROASTING

From Table 4, work rate of subject A while operating the roaster was 1750 J/m for 5kg groundnut seeds and then increased to 3250 J/m when the groundnut seeds increased to 20kg. From Table 5 that, the work rate of Subject B was 2500 J/m for 5kg groundnut seeds and increased to 3400 J/m when the groundnut seed was increased to 20 kg. Generally, work rate increased as the
weight of groundnut in the drum increased, this is because it is more difficult to rotate higher weight (moment of inertia) than lighter weights. More energy is required to rotate heavier loads than lighter loads. However physiological difference among individuals accounts for the variation observed in respect of the two subjects. Basically, this physiological variable is a function of the Oxygen reserves of human and hence their length of sustenance to certain job varies (Tanoubi et al. 2009).

| M (kg) | H1 (b/m) | H2 (b/m) | W1 (J/m) | W2 (J/m) | W (J/m) | T (min) |
|-------|----------|----------|----------|----------|---------|---------|
| 5     | 80       | 92       | 800      | 2550     | 1750    | 21.5    |
| 10    | 78       | 98       | 500      | 3150     | 2850    | 18      |
| 20    | 80       | 102      | 800      | 4050     | 3250    | 22      |

| M (kg) | H1 (b/min) | H2 (b/min) | W1 (J/min) | W2 (J/min) | W (J/min) | T (min) |
|-------|------------|------------|------------|------------|-----------|---------|
| 5     | 80         | 96         | 600        | 3100       | 2500      | 12      |
| 10    | 78         | 98         | 300        | 3500       | 3200      | 17      |
| 20    | 80         | 102        | 600        | 4000       | 3400      | 21.5    |

4 CONCLUSION
Ergonomic studies on IAR manually operated groundnut roaster have been conducted using two women as test subjects. From the results obtained, work rate increases with an increase in loadings. Average work rate of the operators while using the roaster on full load capacity are 3.4kJ/m and 3.25kJ/m for subjects A and B, respectively. These results show that the groundnut roaster is not too energy demanding and can be operated with ease by local oil processors.

NOMENCLATURE
IAR Institute for Agricultural Research , b/m Beats per minutes
J/m Joules per minutes, M Weight of groundnut, H1 Initial heart rate
H2 Final heart rate, W1 Initial work rate, W2 Final work rate
W Work rate

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