



## Performance Evaluation of an Electromechanical Groundnut Roasting Machine

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### A B S T R A C T

#### Keywords:

Groundnut seeds,  
Roasting chamber,  
Conveyor,  
Optimum Performance,  
Roasting time

*The performance evaluation of an electromechanical groundnut roasting machine was conducted with the aim of achieving efficient roasting conditions and eliminating the drudgery associated with roasting groundnut. The machine was tested in the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria using fresh groundnuts purchased at a local market. A total of one hundred and eighty nine experimental tests were carried out. Temperature, mass of the groundnut, moisture content of the groundnut and speed of the machine were considered and varied for the purpose of this research while  $3 \times 3 \times 3 \times 7!$  randomized complete block design was used. The machine was tested using seven different temperature levels of 70°C, 100°C, 150°C, 200°C, 250°C, 300°C and 350°C for three different masses of groundnut while the machine speed was varied.*

*The results showed that changes in machine operating parameters especially roasting temperature, moisture content and machine speed affected significantly the roasting efficiency, conveyance efficiency, quality efficiency and mechanical damage. The maximum values of roasting efficiency of 94.58%, conveyance efficiency of 99.56%, quality efficiency of 99.40% and mechanical damage of 32.35% were obtained at various roasting temperature of 700C, 1000C, 1500C and 2000C, while a minimum value of roasting efficiency of 60.07%, conveyance efficiency of 56%, quality efficiency of 35.99% and mechanical damage of 0.50% were obtained respectively. The optimum performance of the machine was obtained under a temperature range of 150 - 2000C, machine speed of 12.8 rpm and moisture content of 15.8%. The machine roasting capacity was found to be 36.91 kg/hr.*

*Keywords: Groundnut seeds, Roasting chamber, Conveyor, Optimum Performance, Roasting time*

### 1. Introduction

The problem of widespread food insecurity is one of the most serious challenges that face the world with about 840 million undernourished people (Adetunji, 2004). A number of policies and strategies are being initiated to effectively tackle the problem. Current thought in developing economies is that economic growth and food security can be accelerated if proper attention is focused on issues of integrated rural development, regarding farm production, agro-industries, facilitating services, processing and marketing of inputs and outputs (Afonja, 1998).

Roasting, the removal of undesired moisture from a product is an age-old practice followed at various levels. Many agricultural, horticultural and industrial products including chemical and pharmaceuticals are roasted for various purposes like safe storage, easy handling, value addition, further processing and quality improvement (Chavda and

Naveen, 2009).

Many of the agricultural products are dried at the farm level to prevent deterioration and improve storage properties (Chavda and Naveen, 2009). Reduction of moisture in the groundnuts through roasting method plays an important role in the storage and marketing of peanuts. Peanuts are usually harvested at high moisture content and then artificially dried to a safe storage moisture of 7-8% w.b. (Woodroof, 1983). The groundnut moisture content must be reduced to 10.5% or below before it can be graded and marketed (Francisco et al., 2006). Roasting results in further weight loss (due to drying of moisture) of 3 to 4%. About 80 percent of the edible groundnuts are roasted for further processing into snack foods and peanut butter (GSPNews, 2004).

Groundnut roasting is one of the most important tasks in the processing of groundnut seeds for the production of oil, cake or snack. The seed contains on the average about 40-50% oil, and is rich in protein, making it a valuable feed for poultry (Asiedu, 1989). The main commercial product of groundnut seed processing is highly mechanized in developed countries such as roasted salted peanuts. However, in the developing countries like Nigeria, and indeed in

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many West African Countries traditional method of processing is the norm (Norde et al., 1982). This is very cumbersome and labour intensive. Groundnut seeds are roasted traditionally by constant stirring of the groundnut seeds in an open mild steel pan over an open wood fire (Kabri et al., 2006).

Groundnut roasting methods have been the main constraints in improving peanut quality to meet industrial market standards. Groundnut generally contain about 35-55% moisture, without reducing moisture content to about 10%, the produce is quite susceptible to contamination by moulds (Athapol et al., 1992). This conditions leads to the development of aflatoxins when spoilage occurs, there is high demand for roasted and toxin free groundnut. The specific objectives of this work are to: carry out performance evaluation of an electromechanical groundnut roasting machine using different variables of speed, moisture content, mass and temperature and determine the optimum operating conditions for efficient roasting of groundnut for small and medium scale processors.

The groundnut can be processed into a number of edible products such as peanut oil, peanut butter, salted peanuts, and a number of confectionary products including peanut candies brittles, crisps, caramel tops, peanut chews, peanut kisses, chocolate peanut purge, chewy peanut nougat, cut grained peanut nougat, peanut candy desserts and peanut bakery sweets. In addition peanut can be processed to produce peanut flour, peanut protein, peanut milk and curd, peanut cheese and peanut paste for seasoning vegetables.. Several non food peanut products can be manufactured using groundnut such as soaps, cosmetics, medicines, shaving creams, pomades and lubricants. The residue left after oil extraction from groundnut kernels is called cake and is a nutritional cattle feed or good manure. Peanut cake under hygienic conditions can also be used for human consumption.

Peanuts are traditionally roasted by stirring in hot sand in a flat-bottom roasting pot over a hot flame which is laborious and has limited capacity. Roasting of groundnut is done in order to serve as a means of cooking and this is done by indirectly placing it on open pot that contained heated sand. Over few minutes, the groundnut gets done. This is done mechanically by placing groundnut in mechanical roaster at a high temperature (Kabri et al., 2006).

There are two primary methods for roasting peanuts, dry roasting and oil roasting. Also, there are existing methods of groundnut roaster which are traditional, solar and mechanical roasting. The process of roasting agricultural product is affected by the following roasting parameters (Olalusi, 2011): temperature of the roasting chamber, humidity level of the roasting chamber, flow direction and intensity (flow rate) of the drying air (if present, area of exposed surface of the food particle, composition and structure of the food and speed and Pitch of Screw conveyor. Kabri et al, (2006) evaluated a manually operated drum groundnut roaster with the aim of achieving efficient roasting of groundnut. The machine was designed and tested using SAMNUT-10(RMP-9), SAMNUT-10RMP-12 and ICGV-SM-93523 as groundnut samples. The

machine utilizes the principle of convection drying method. The major components of the machine are; frame, seed drum, offloading handle, sprocket, chain, axial fan, charcoal tray and heat control base. The results showed that temperature and machine speed has significant effect on roasting evaluation parameters. It was concluded that the machine can be improved to obtain maximum roasting efficiency.

## 2. Materials and Methods

### 2.1 Research material and Instrument

The major material used to carry out the performance evaluation of an electromechanical roasting machine was fresh groundnut which was obtained from groundnut leguminous crop. The groundnut was sourced from local markets in Ogbomoso, Oyo State. The roasting machine was designed and fabricated in 2011 at the Agricultural Engineering Department of the Federal University Technology Akure by Engr. Prof. O.J. Olukunle through Step-B project. The instruments used to measure the processing parameters were: thermocouple thermometer (digital k-type), tachometer, weighing balance, stopwatch and grain moisture meter respectively .

### 2.2 Description of the electromechanical groundnut roasting machine

The groundnut roaster consists of a cylindrical drum which was placed horizontally on a frame. Inside the drum was affixed a screw conveyor which moves and mixes the groundnut from the inlet point of the roaster to the opening point. Heat was supplied to the roasting chamber through conduction principle which was placed beneath the roasting chamber. The temperature of the drum could reach 1000C and be maintained at  $\pm 9$ . The length of the heater was nearly equivalent to the length of the roasting chamber. Fibre material was used as insulation between the roasting chamber and the outer cover of the machine in order to prevent heat loss and hazards due to touching of the outer part of the machine. The heater and the screw conveyors were regulated with the aid of electrical control panel. Temperature was measured and controlled by a temperature regulator and digital (k-type) thermocouple to which thermocouple wires were attached. The thermocouple wire was linked into the machine to the base of the roasting chamber.

### 2.3 Experimental Procedure

A total of one hundred and eighty nine experimental tests: different processing conditions (temperature, mass of the groundnut, moisture content of the groundnut and machine speed) were considered for the purpose of this study. Investigations were carried out on the effects of processing conditions of groundnut, such as moisture content, mass, machine speed to achieve the best performance. The time taken for each experiment was recorded using a stopwatch. While fresh groundnut was loaded manually through the hopper using different feed rates in each case and the following parameters was measured: initial moisture content of the groundnut Mc1 (%wb), final moisture content of the roasted groundnut Mc2 (%wb), initial mass of the groundnut M1 (kg),

mass of groundnut collected  $M_2$  (kg), mass of the roasted groundnut ( $M_r$ ), mass of the unroasted groundnut  $M_u$  (kg), mass retained  $M_R$  (kg), mass of groundnuts broken (unwhole)  $Q_T$  (kg), mass of groundnuts burnt,  $Q_b$  (kg), time taken to roast groundnuts or Operating time  $T$  (min) shaft speed  $v$ (s) temperature, ( $^{\circ}C$ ). The data was analyzed using microsoft excel and interpreted. The data obtained was then used to calculate the efficiencies, and mechanical damage.

#### 2.4 Performance evaluation parameters

The following evaluation parameters were determined from the results obtained, as reported by kabri et al., (2006) and Mirani et al., (2001).

$$R.C = M_2/T \text{ (Kabri et al., 2006)} \dots\dots\dots (1)$$

$$R.E = M_r/M_1 (\%) \dots\dots\dots (2) \text{ (Kabri et al., 2006)}$$

$$C.E = (M_2/M_R + M_2) \% \dots\dots\dots (3) \text{ (Mirani et al., 2001)}$$

$$M.E = (M_2 - Q_T/M_1) \% \dots\dots\dots (4) \text{ (Kabri et al., 2006)}$$

$$M.D = (Q_b/M_2) \% \dots\dots\dots (5) \text{ (Kabri et al., 2006)}$$

Where:

- R.C = Roasting capacity%
- $M_2$  = mass of groundnut collected (kg)
- $T$  = Time taken to roast groundnuts (min).
- R.E = Roasting efficiency%
- $M_r$  = The mass of the roasted groundnut (kg)
- $M_1$  = The initial mass of the groundnut (kg)
- C.E = Conveyance efficiency%
- $M_2$  = mass of groundnuts collected (kg)
- $M_R$  = mass retained (kg).
- M.E = Quality efficiency%
- $M_2$  = mass of groundnut collected (kg)
- $Q_T$  = The mass of groundnuts broken (kg)
- $M_1$  = The initial mass of the groundnut (kg).
- M.D = Mechanical damage%
- $M_2$  = mass of groundnut collected (kg)
- $Q_b$  = Mass of groundnuts burnt (kg).

### 3. Results and Discussions

#### 3.1 Capacity and efficiencies of an electromechanical groundnut roaster at appropriate machine speed and variable temperature

In Table 4.1, the roasting efficiency (R.E) of the machine increases with temperature but at a point the roasting efficiency started reducing as a result of constant high temperature which shows the significant of heat energy. The highest roasting efficiency (R.E) of 94.58% was obtained at temperature of 200°C. The groundnut roaster

proved capable of producing high quality of groundnut at 200°C. It took 5.73 min to roast groundnut at 15.8% (w.b) to reach a final moisture content of 6.80% (w.b). The initial moisture content of groundnut used during this study varied between 20, 15.8 and 9.5% (w.b). The variations were due to the various treatments the groundnuts were subjected to.

#### 3.2 The effect of temperature on roasting efficiency at variable machine speed and product mass

Figures 4.1, 4.2 and 4.3 show the effect of temperature on roasting efficiency at constant machine speed, moisture content and mass of groundnuts within the experiments. The results show that the roasting efficiency increases as the temperature increases with the highest roasting efficiency of 84.04% recorded at the temperature of 200°C, machine speed of 6.6 rpm, moisture content of 20% and at the groundnut mass of 500g for the experiments in the Figure 4.1. The higher the roasting temperature the higher the roasting efficiency, however, increasing the roasting temperature beyond 200°C reduced the roasting efficiency. The curve slightly returned when the groundnut has been roasted to the minimum moisture level or eatable point and any further increase in temperature reduced the roasting efficiency. This phenomenon might be due to the heat velocity and kinetic energies impacted to the moisture particles by the high temperature.

However, as the moisture is released, reduced and small heat energy would be needed to break the bonds of the groundnut into two at a point when there is increase in roasting temperature there would be reduction in roasting efficiency. The reduction in roasting efficiency occurred at a point when the groundnut brownish colour changed to black.

#### 3.3 The effect of temperature on variation of conveyance efficiencies

Figures 4.4, 4.5 and 4.6 show the effect of temperature on variation of conveyance efficiencies at constant machine speed, moisture content and mass of groundnut within the experiments. The results showed that the conveyance efficiency decreased as the temperature increased with the highest conveyance efficiency of 99.56% recorded at the temperature of 70 °C, machine speed of 12.8 rpm, moisture content of 9.5% and at the groundnut mass of 2000g for the experiments.

The conveyance efficiencies were very high yet there was variation in efficiencies due to the fact that the experiments were subjected to different temperature. It was clearly observed in figures 4.6 to 4.7 when compared that there was increase in temperature and reduction in conveyance efficiency as a result of heat energy applied which increased the linear expansivity within the metal used in the construction of the roasting drum and conveyor. The results showed that increase in temperature applied resulted in increase in clearance between the conveyor and the roasting drum. Hence, increase in heat energy supplied beyond what was needed, this affected conveyance of groundnut roasted within the roasting drum and this led to reduction and variation in conveyance efficiency in experiment.

**Table 4.1: The capacity and efficiencies of the roasting machine at constant machine speed and variable temperature**

Speed (rpm)	Temp ( <sup>o</sup> C)	R. C. (Kg/hr)	R. E. (%)	C. E. (%)	M. E. (%)	M. D (%)
12.8	70	9.35	44.20	99.52	99.13	0
	100	12.27	59.10	99.36	98.95	0.50
	150	15.20	72.21	98.26	95.18	2.57
	200	19.80	94.58	97.77	91.58	3.70
	250	19.65	94.03	97.45	90.03	3.72
	300	19.67	93.45	97.26	88.95	4.81
	350	19.46	91.96	96.20	85.96	5.43

Where: R.C = Roasting capacity; R.E = Roasting efficiency; C.E = Conveyance efficiency  
M.E = Quality efficiency; M.D = Mechanical damage

### 3.4 The effect of machine speed on roasting efficiency

As the speed of the machine increases for a particular mass and moisture content, roasting efficiency reduces. In Figure 4.8, as the speed increases from 6.6 – 19 rpm; roasting efficiency reduces from 83.90% to 62.50%. The reason for this reduction in roasting efficiency is because at high speed the heat within the roasting chamber did not have real impact on the groundnuts and the conveyor moved the groundnuts within a short time from the inlet to outlet. Therefore, it was concluded the higher the speed the lower the roasting efficiency.

### 3.5 The effect of temperature on roasting time

Figures 4.9, 4.10 and 4.11 show effect of temperature on roasting time at constant machine speed, moisture content and mass of groundnut within the experiments. It was observed that the maximum roasting time of 8.99 min was recorded at 700C temperature and machine speed of 6.6 rpm while the minimum roasting time 2.8 min was recorded at 3500C temperature and machine speed of 19 rpm. Therefore, the higher the roasting temperature in the roasting chamber, the lower the roasting time. The results show that the roasting time reduced as the temperature increased with the maximum roasting time of 8.99min recorded at the mass of 500g, machine speed of 6.6 rpm, moisture content of 9.5% and temperature of 700C for the experiments in the Figure 4.9. It can be seen from the curves that it took 8.9min for machine speed of 6.6 rpm with initial moisture content of 9.5% (w.b), 5.88min for machine speed of 12.8 rpm with initial moisture content of 9.5% (w.b) and 3.09 min for machine speed of 19 rpm with initial moisture content of 15.8 (w.b) to reduced moisture level of the groundnuts. This is in agreement with the findings of other researchers (Kabri et al., 2006; Thaddus, 2004 and Athapol et al., 1992).

### 3.6 The optimum roasting efficiency within the experiments

Figure 4.12 shows optimum roasting efficiency within the experiments. The result shows that the roasting efficiency is optimum at the experiments 22 and 23: the highest roasting efficiency of 94.58% obtained at experiment 23 and processing conditions also recorded at the temperature of 2000 C, machine speed of 12.8 rpm, mass of 2000g and moisture content of 15.8%. The discharged groundnut moisture content was determined using grain moisture meter however, the moisture content reduced from 15.8 to 6.8%. From the result it can be recommended that the roasting machine can work effectively under the following operating parameters; temperature of 2000C, machine speed of 12.8 rpm, mass of 2000g and moisture content of 15.8%.

### 3.7 The optimum conveyance efficiency within the experiments

Figure 4.13 shows optimum conveyance efficiency within the experiments. The result shows that the conveyance efficiency is optimum at the experiments 23 and 26 correspondingly: the highest conveyance efficiency of 99.56% obtained at experiment 26 and processing conditions also recorded at the temperature of 700C, machine speed of 12.8 rpm, mass of 2000g and moisture content of 9.5%.

### 3.8 The optimum mechanical damage within the experiments

The figure 4.14 shows optimum mechanical damage within the experiments. The results show that the mechanical damage is optimum at the experiment 1 and 5: the highest mechanical damage of 32.35% obtained at experiment 5 and processing conditions also recorded at the temperature of 3500 C, machine speed of 12.8 rpm, mass of 500g and moisture content of 15.8%.

## 4. Conclusion

The performance evaluation of an electromechanical groundnut roasting machine was carried out with the aim of improving groundnut roasting efficiency and eliminating the drudgery associated therewith. Roasting capacities of the groundnut at different shaft speed of 6.6 rpm, 12.8 rpm and 19 rpm were 12.55 kg/hr, 20.51 kg/hr and 36.91 kg/hr respectively. The roasting efficiencies were up to 94.51%, 94.51% and 87.97% respectively. The conveyance efficiencies were 99.02%, 99.56% and 97.78% respectively. The quality efficiencies were 98.88%, 99.40% and 97.19% respectively and mechanical damages were 31.92%, 32.35% and 21.02% respectively. Nevertheless, the machine has overcome the limitations of groundnuts roasting. Therefore, efficient and precise groundnut roasting is achievable with an electromechanical groundnut roaster. It can be concluded from the experiment that as the temperature increases, the conveyance efficiency decreases due to thermal expansion of the material used in the roasting chamber. The machine has many comparatively favourable attributes and is to be preferred to the old traditional method of roasting groundnuts. The roasting capacity, roasting efficiency conveyance efficiency, quality efficiency and mechanical damage of the machine has economic advantage over manual method further enhances its suitability for small-scale groundnuts processors. The results obtained further shows that the machine could be very useful in a situation where considerable quantities of groundnuts have to be roasted in limited time.

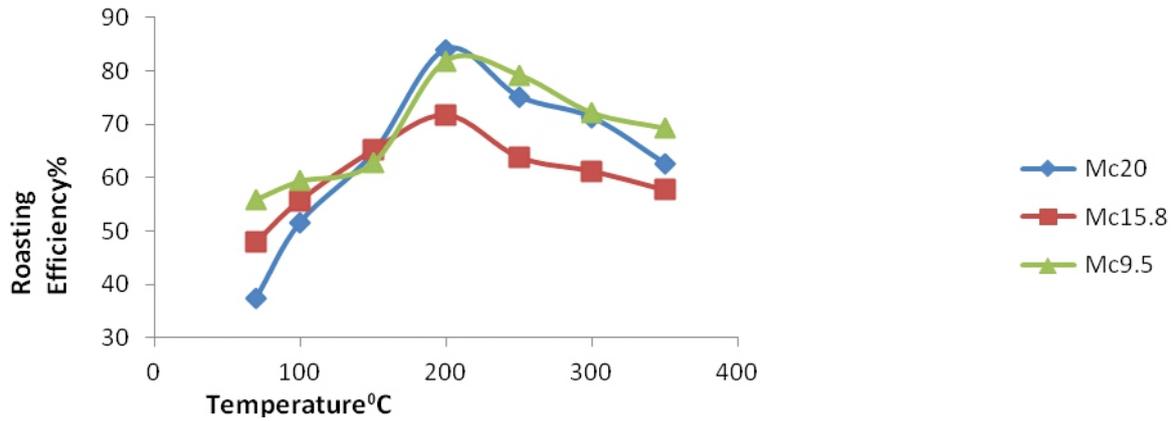


Figure 4.1: The effects of temperature on roasting efficiency at speed 6.6 rpm and mass 500g

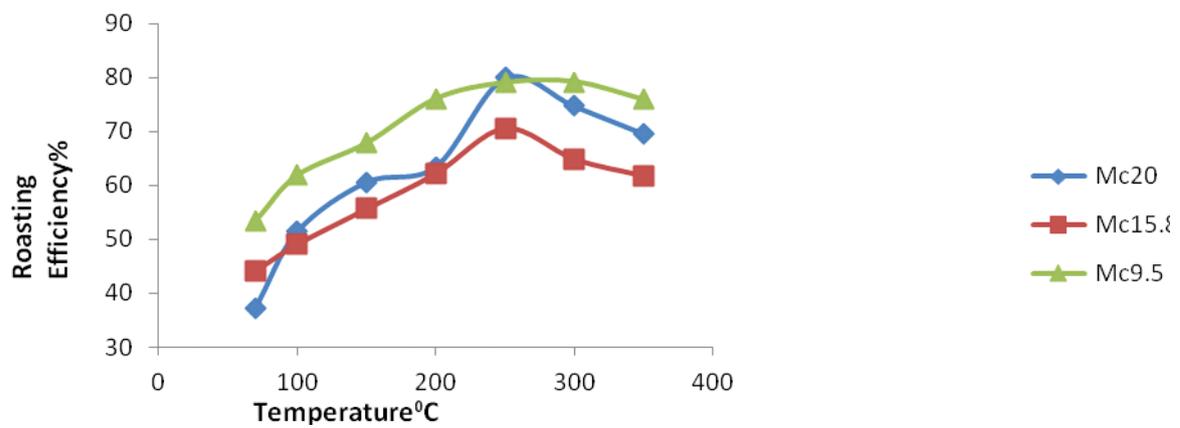


Figure 4.2: The effects of temperature on roasting efficiency at speed 12.8 rpm and mass 500g

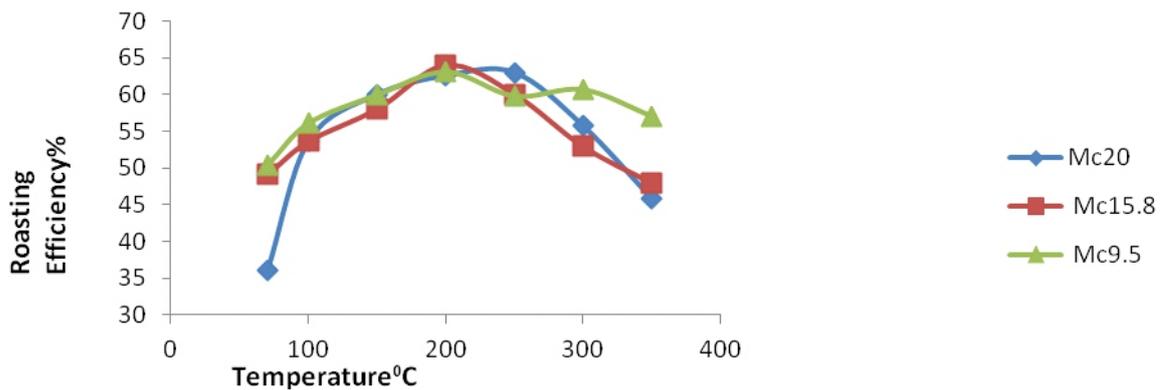


Figure 4.3: The effects of temperature on roasting efficiency at speed 19 rpm and mass 500g

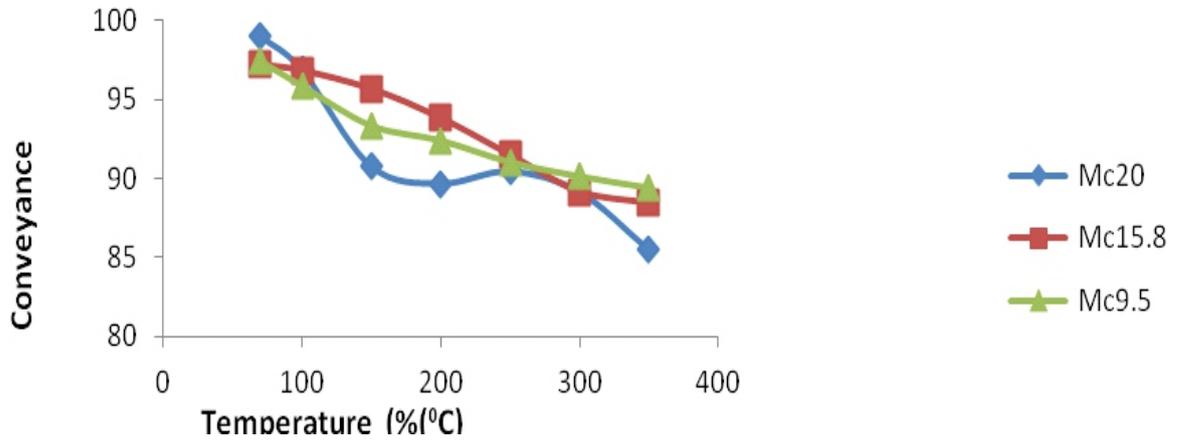


Figure 4.4: The effects of temperature on conveyance efficiency at speed 6.6rpm and mass 2000g

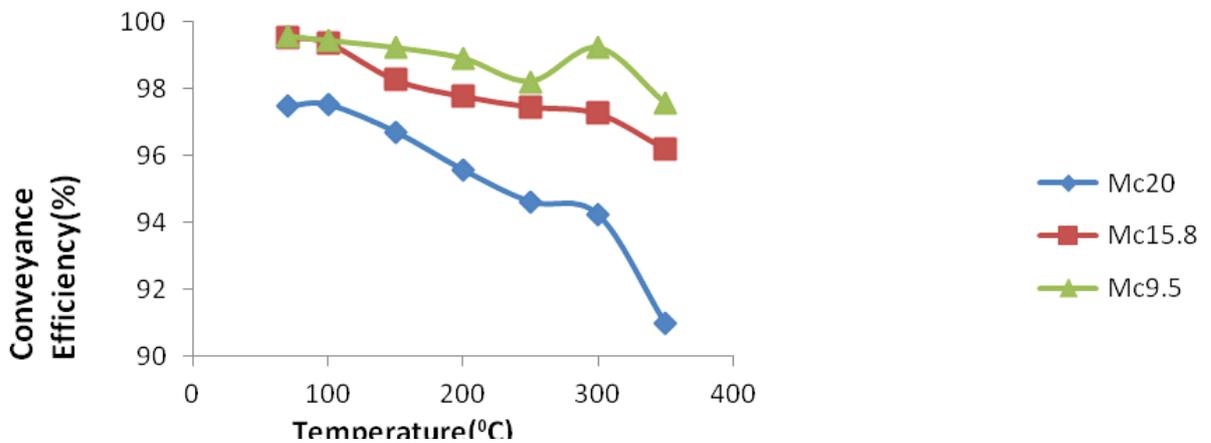


Figure 4.5: The effects of temperature on conveyance efficiency at speed 12.8 rpm and mass 2000g

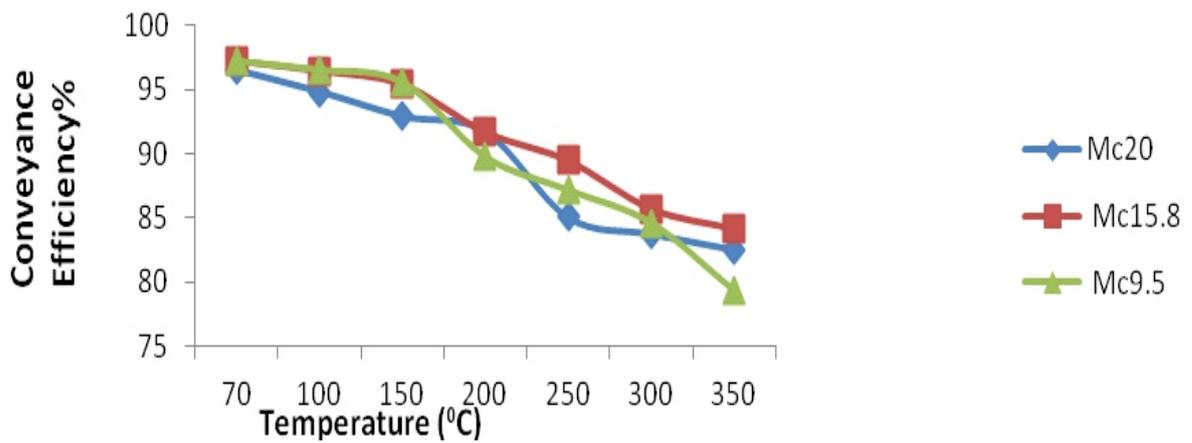


Figure 4.6: The effects of temperature on conveyance efficiency at speed 19 rpm and mass 2000g

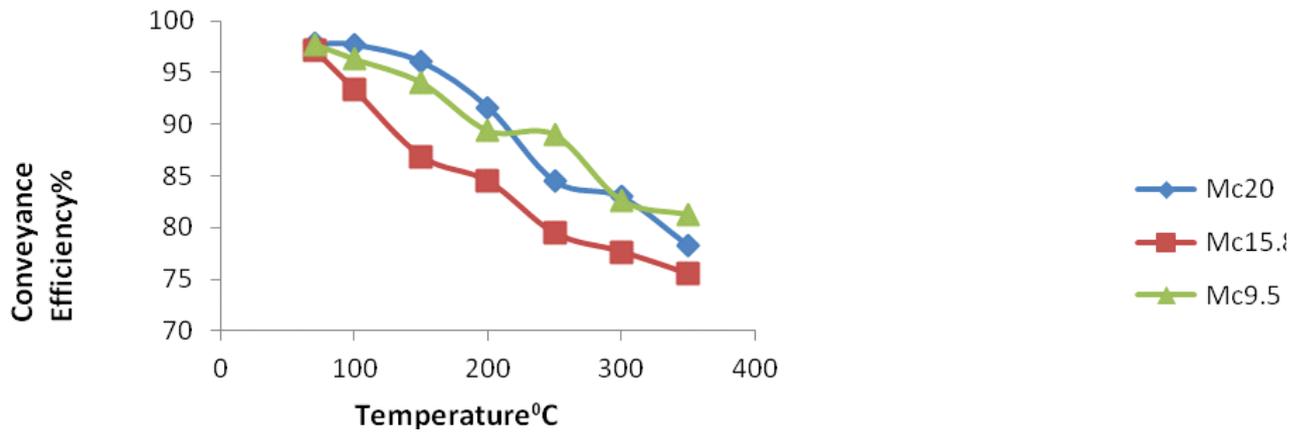


Figure 4.7: The effects of temperature on conveyance efficiency at speed 6.6 rpm and mass 500g

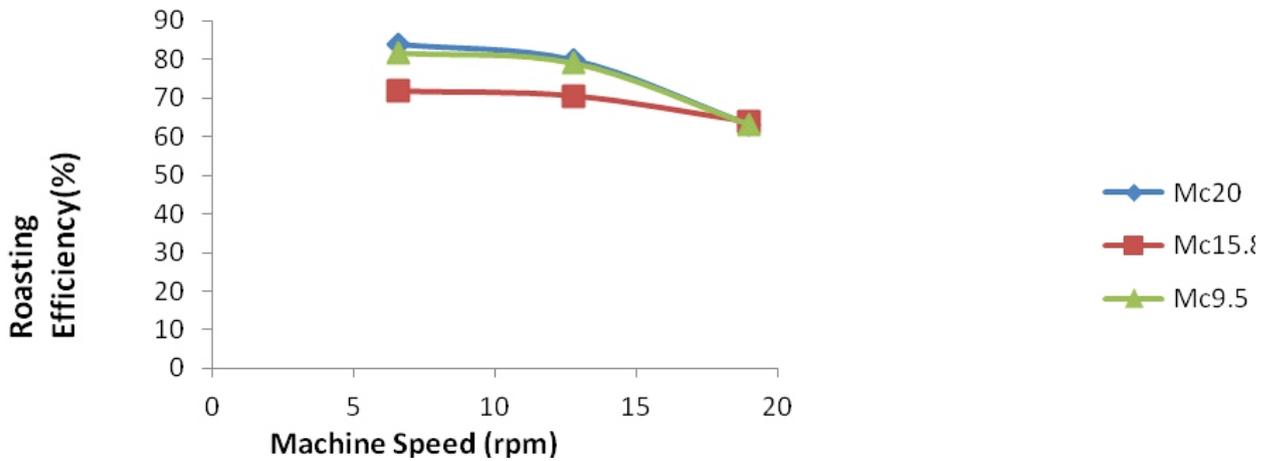


Figure 4.8: The effects of machine speed on roasting efficiency at mass 500g

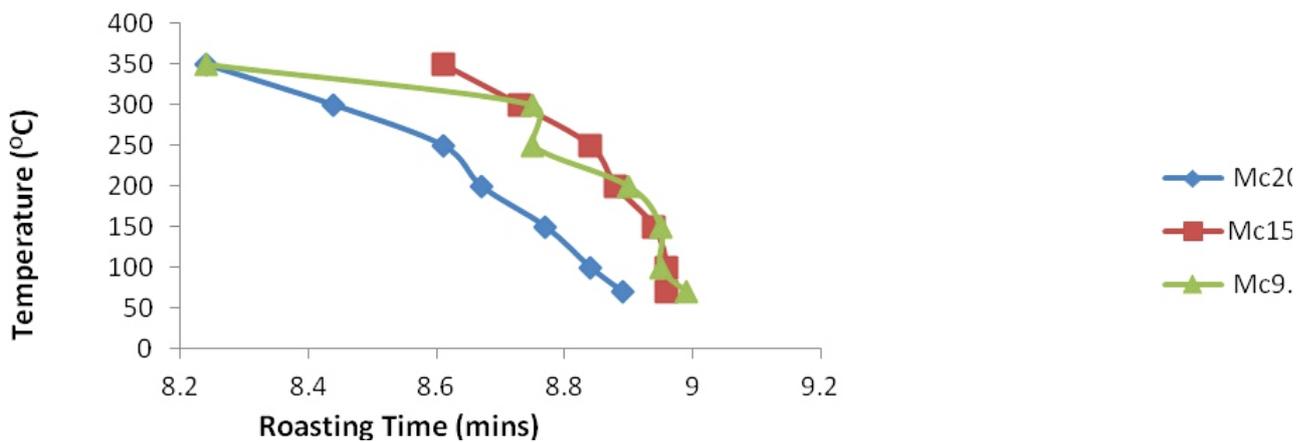


Figure 4.9: The effects of temperature on roasting time at speed 6.6 rpm and mass 500g

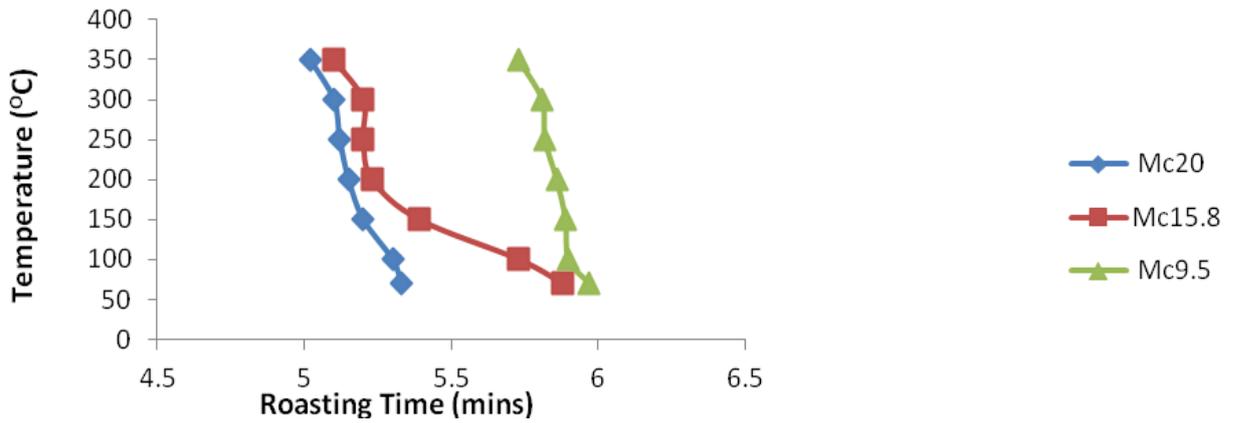


Figure 4.10: The effects of temperature on roasting time at speed 12.8 rpm and mass 1000g

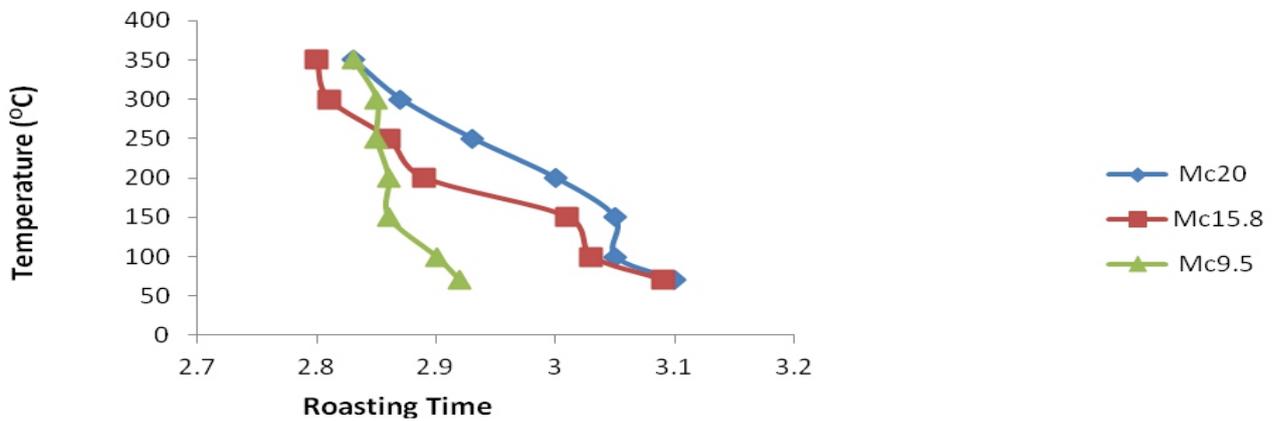


Figure 4.11: The effects of temperature on roasting time at speed 19 rpm and mass 2000g

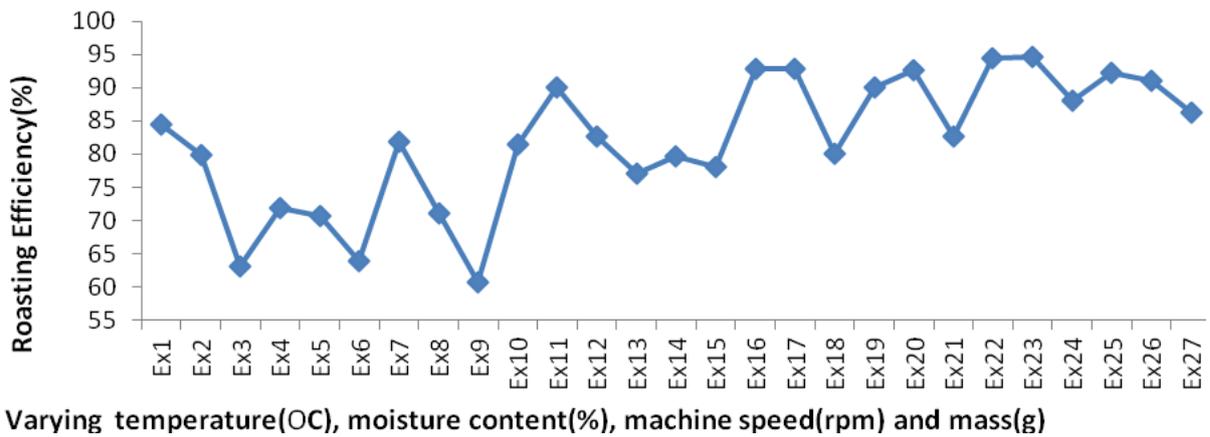


Figure 4.12: Optimum roasting efficiency experiments between the groups

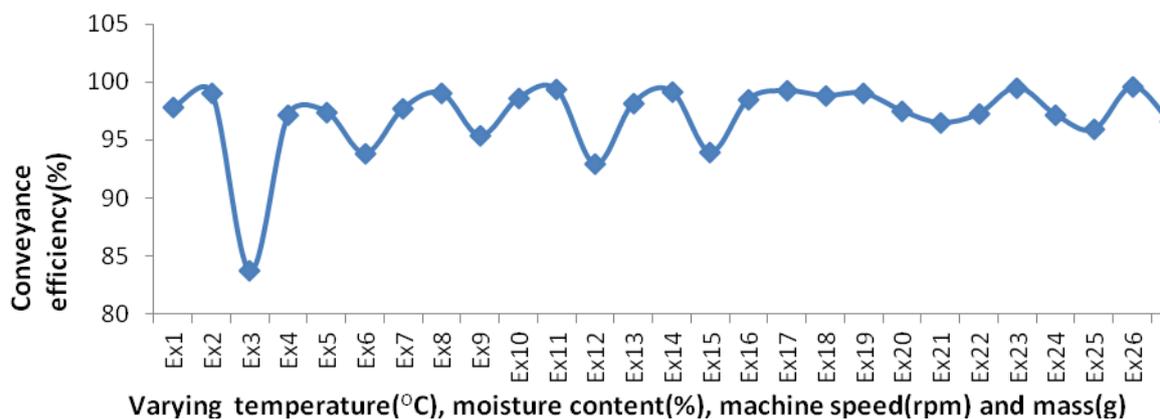


Figure 4.13: Optimum conveyance efficiency experiments between the groups

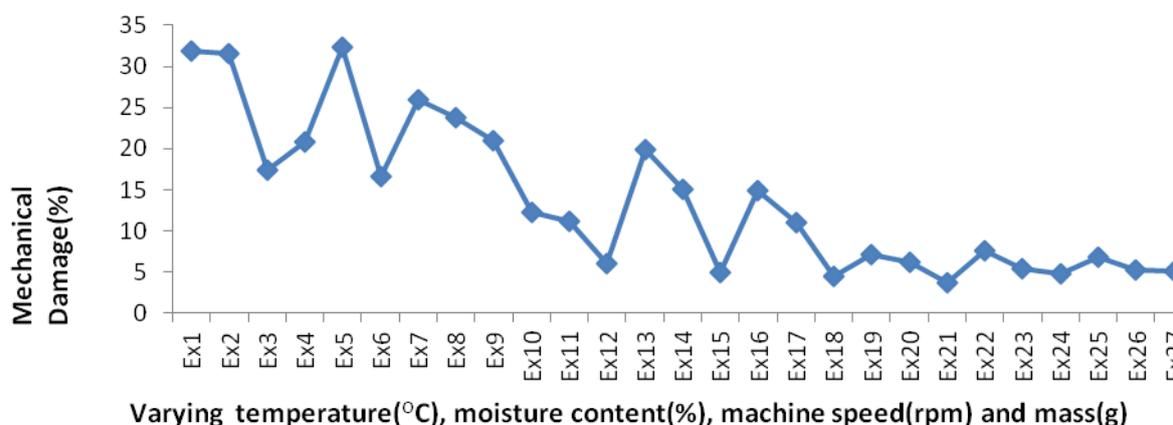


Figure 4.14: Optimum mechanical damage experiments between the groups

Mc = Moisture content, M = Mass, g = Gramme, rpm = revolution per minute, R.C = Roasting capacity, kg/hr = kilogramme per hour, kg = kilogramme and Ex = Experiment

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