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Research Paper

Performance evaluation for maize roasting machine

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ABSTRACT

The performance evaluation of a maize roasting machine was carried out with the aim of achieving efficient roasting of maize kernel. The performance evaluation of the machine was carried out using maize purchased at Ejigbo market in Osun State as sample. The machine was tested with 1000 g of peeled and unpeeled maize with three different temperatures of 200, 300 and 350°C and four different speeds of 6.6, 15 and 19 rpm, respectively. The machine optimum functional efficiency was recorded for peeled and unpeeled maize at a temperature of 200°C and the speed of 6.6 rpm which were 76 and 80.9%, respectively. Also, the machine optimum conveyance efficiency recorded for both peeled and unpeeled maize were 76.84 and 81.4%, respectively at a temperature of 200°C and the speed of 6.6 rpm. Hence, the two evaluation parameters: speed and temperature have significant effect on the performance of the machine. The experiment shows that as the temperature increases, the conveyance efficiency decreases due to linear expansivity of the metal. The temperature of 200°C with the speed of 6.6 rpm shows the optimum performance of the machine.

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Key words: Performance evaluation, maize, roasting machine, throughput capacity, conveyance efficiency, roasting efficiency, temperature and speed.

INTRODUCTION

Maize roasting is one of the most important tasks in the processing of maize kernels for the production of corn starch, corn oil, corn syrup, corn sugar and by-product. The kernel contains on the average about 40 to 50% oil, and is rich in carbohydrate and protein, making it a valuable feed for humans and poultry (Purseglove, 1992; Osagie and Eka, 1998). The main commercial product of maize seed processing is highly mechanized in developed countries. However, in the developing countries like Nigeria and indeed in many West African Countries, traditional method of processing is the norm. This is very cumbersome and labour intensive.

Maize seeds are roasted traditionally in an open mesh wire over an open wood fire (Kochhar, 1986; Fakorede et al., 1993). The kernel of maize has a pericarp of the fruit fused with the seed coat referred to as "caryopsis", typical of the grasses, and the entire kernel is often referred to as the "seed" (Abdulrahaman and Kolawole, 2008). The grains are about the size of peas, and adhere in regular rows round a white, pithy substance, which forms the ear. An ear contains about 200 to 400 kernels, and is from 10 to 25 cm (4 to 10) in length (Ekpenyoung et al., 1977). The average caloric content of the whole meal from maize is 3,578 Calories per kilogram. Maize is recognized to have a high medicinal value as it contributes to the effectual cure of some illness. Abdulrahaman and Kolawole (2006) and Hartmans (1985) explained some of the medicinal values of maize.

The global production of maize is estimated to be about 300 million tons per year. 145 million (or about 50%) are produced in USA alone (Ihelarouye and Ngoddy, 1965; Kochhar, 1986; Purseglove, 1992). The seed - coat or pericarp is characterized by a high crude fibre content of about 87%, which is constituted mainly of hemicellulose (67%), cellulose (23%) and lignin (0.1%) as stipulated by Burge and Duensing (1989).

The germ is characterized by a high crude fat content, averaging about 33%. The germ also contains a relatively high level of protein (18.4%) and minerals (Burge and Duensing, 1989). About 92% of the protein in teosinte comes from the endosperm. Several researchers have reported on the protein content in maize kernel (Bressani and Mertz, 1958).

Vitamins in large quantities have also been found present in maize and this implies that it is a complete food for low level

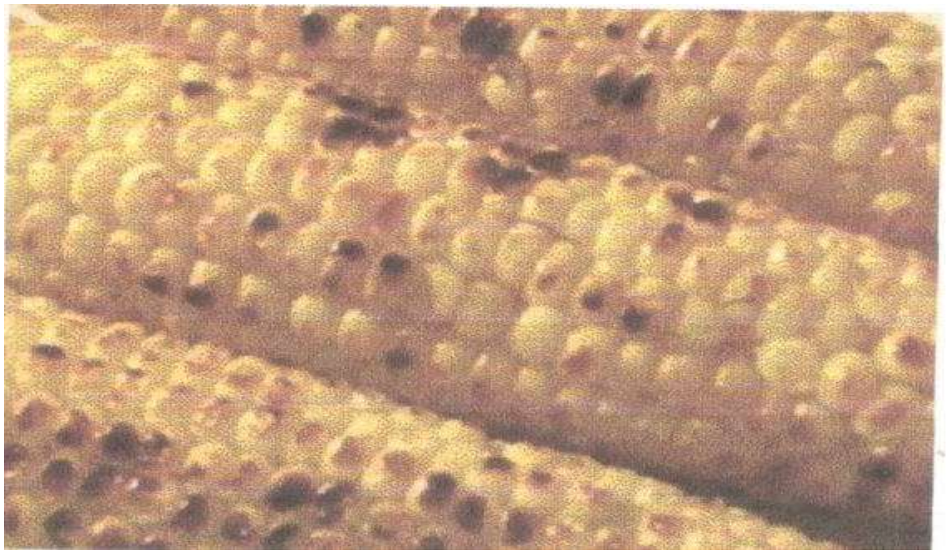

Figure 1: Roasted corn.

income people. A report from Osagie and Eka (1998) and Ekpenyoung et al. (1977) affirmed that maize is the second most important cereal crop in Nigeria ranking behind sorghum in the number of people it feeds.

Maize uses includes: corn starch, corn oil, maize gluten, grain alcohol, starch source for beer, commercial animal food products, popcorn production, plastic, fabrics, adhesives, livestock and poultry feed, biofuel and fodder to mention a few (Olaofe, 1988; Burge and Duensung, 1992).

Maize processing starts from the harvesting stage to the last point in the chain order: Harvesting → Dehulling → Drying or Roasting → Shelling Winnowing → Further Processing. Drying is of great importance because it prevents germination, growth of bacteria and fungi and retards considerably the development of mites and insects. One of the problems in tropical areas is high relative humidity due to rainfall, poor insulation levels and shortage of household labour. Roasting is done to maize in order to serve as a cooking means and this is done by directly placing it on fire unthrashed and it takes about 15 to 20 min. Thus, it is done mechanically by placing threshold maize kernels in mechanical dryers at very high and controlled temperature.

Ayatse et al. (2003) reported that the proximate analysis showed no significant difference ($p > 0.05$) between raw and roasted maize in ether extract, crude protein, crude fibre, ash and carbohydrate content, except moisture content ($p > 0.05$), which showed a 42.3% decrease. Elemental composition analysis showed decreases of potassium (13.8%) and calcium (41.1%). Significant differences ($p < 0.05$) were observed for vitamins B_t, B_2 and C contents with 26.8, 32.4 and 35.1% destruction, respectively. Amino acid analysis showed losses for lysine (26.7%), iso - leucine (20.8%) and leucine (23.4%). There was significant ($p < 0.05$) variation in phytic acid, oxalic acid, tannin and hydrocyanic acid with reductions of 15.4, 6.02, 51.3 and 34.6%, respectively. This result simply shows that there is a direct effect of temperature and other factors on the nutritive values of the maize product depending on the extent of exposure to high temperature or the level of temperature. Figure 1 shows the sample of roasted corn.

Factors affecting mechanical roasting were listed by Bressani and Mertz (1958), Adenola and Akinwumi (1993) as temperature of the drying chamber, humidity level of the drying 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 food, speed and pitch of screw conveyor. Burge and Duensing (1989) discussed processing and dietary fiber ingredient applications of corn bran, while Watson (1987) and Purseglove (1992) worked on structure and composition of maize as well as, complexity of carbon content of maize. Dielaronye and Ngoddy (1965) and Abdulrahaman (1997a) reported that processing of maize includes: harvesting, dehauling, drying or roasting, shelling, winnowing and further processing. Watson (1987) and Been et al. (2002) reported on the most popular models of corn roasters being TCR (Texas Corn Roaster), Original Corn Roaster, and roasters made by Holstein. These three manufacturers make excellent corn roasters. The models are shown in Figure 2.

MATERIALS AND METHODS

Maize kernel was used to carry out the performance evaluation of the roasting machine which was obtained from Ejigbo market in Osun State. White maize was adopted for the experiment and kept in air tight place in order to prevent moisture re -absorption and maintain constant moisture content throughout the course of the experiment. Some of the experiment used include: the electric digital weigh balance, bowls, grain moisture meter and the tachometer which was

Figure 2: TCR's Corn roaster.

Figure 3: The maize roaster.

used for measuring the speed of the grains conveyor shaft.

Description of the maize roaster

The maize roaster consisted of a cylindrical drum which was placed horizontally on a frame. Inside the drum was affixed a screw conveyor which moves and mixes the maize kernels from the inlet point of the roaster to the exit point. Heat was supplied to the roasting chamber by a means of electric heating rods placed beneath the roasting chamber. The length of the rods was nearly equivalent to the length of the roasting chamber. Fiber glass 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. The temperature was measured and controlled by a temperature regulator to which thermocouple wires were attached. The thermocouple wire was linked into the machine to the base of the roasting chamber. Figure 3 shows

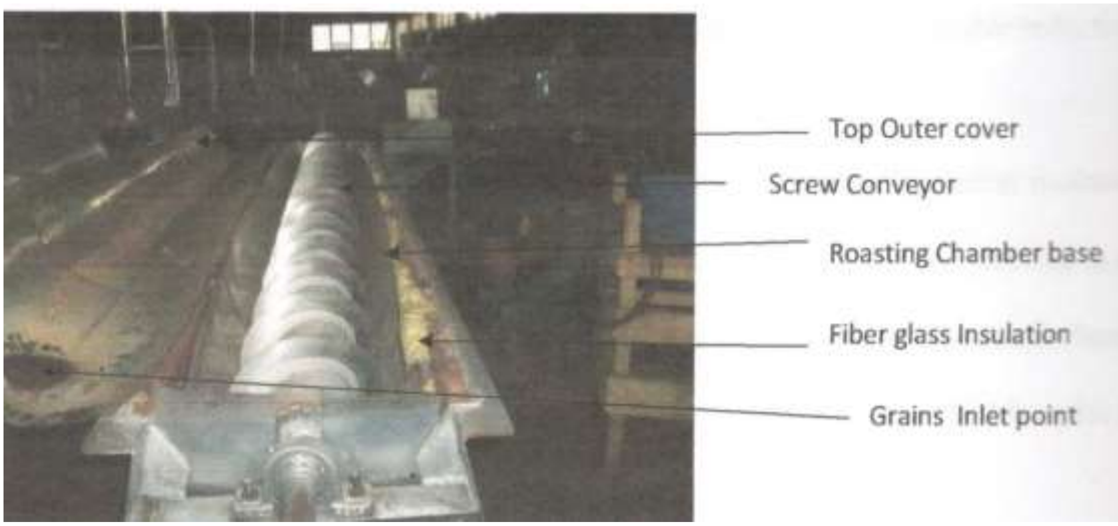

Figure 4: Internal view of maize roaster.

the roasting machine, while and Figure 4 show the internal view of the machine.

Mode of operation

The machine was powered by variable electric gear motor which is connected to the screw conveyor by means of belts and pulley. When the machine is switch on, the screw conveyor moves and then the heating elements are powered on. The temperature regulator is set to a certain temperature of about 200°C and at a point when the temperature is up to that level, the regulator switches off the heating element. When the materials are fed into the machine, the screw conveyor pushes the grains forward and as well, mixes them in order to have uniform contact with the heating surface. The roasted grains are collected at the exit point of the machine.

Experimental procedure

The experiment was carried out at four speeds of the screw conveyor. This was done in order to check for the effect of auger speed on the evaluation parameters. The speeds chosen were 6.6, 11, 15 and 19 rpm, respectively. All the speeds were derived using various pulley sizes on the screw conveyor and the power or motion generated from an adjustable reduction gear motor which had the highest speed of l00 rpm.

Grains of constant mass (1000 g) were introduced to the machine. The initial moisture contents of the grains were recorded before introducing to the roaster and the temperature as well recorded. The final weight and moisture content of the products were measured. Some products were left in the roaster so these were retrieved and the weight measured in order to check for the conveyance efficiency of the roaster.

The effects of roasting temperature were checked by conducting the experiments at three temperature levels of 200, 300 and 350°C, respectively. In addition, some maize kernels were peeled and roasted at the same temperatures in order to check for the optimum grain condition for the roaster to achieve the best performance. The time taken for each experiment was recorded using a stopwatch.

Evaluation parameters

The machine was checked at four conditions of speed and three temperature conditions. The evaluation parameters used to check the machine were:

1) Machine throughput capacity;
2) Conveyance efficiency;
3) Roasting efficiency.

All aforementioned parameters were derived for each test and the overall values recorded and compared.

Determination of evaluation parameters

Throughout capacity

The machine was fed at constant feed rate and the throughput capacity derived as the ratio of collected product to the time spent in the roasting chamber, this is given mathematically as:

$$C_t = \frac{M_f}{t} \qquad (1)$$

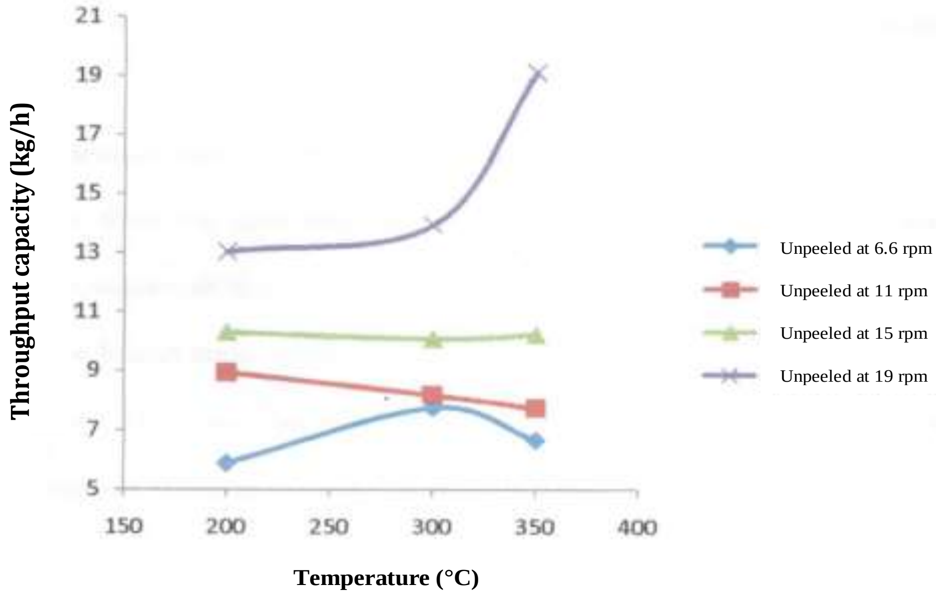

Figure 5a: Effects of temperature, speed and treatment on throughput capacity.

Where:

C_t = Throughput capacity;
Mf = Final mass of collected product;
t = Roasting time.

Roasting (Functional) efficiency

The roasting efficiency was calculated as the ratio in percentage of the collected products to the initial mass of products let into the machine. This is represented mathematically as:

$$R.E = \frac{M_f}{M_f} \times 100\% \qquad (2)$$

Where, M_f = Final mass of collected product; MI = Initial mass of maize and MI is constant all through experiment and is given as 1000 g.

Conveyance efficiency

Some products were observed to be left in the machine unconveyed and the percentage of conveyed products is given as:

$$C.E = \frac{M_f}{M_r + M_f} \times 100\% \qquad (3)$$

Where:

C. E. = Conveyance efficiency;
M_r = Mass of retained products (retrieved from the roaster);
Mf = Final mass of collected product.

RESULTS AND DISCUSSION

The results of performance evaluation of maize roaster are as follows:

Effect of temperatures, speed and treatment on throughout capacity

The results from the experiments showed that the throughput capacity of the machine had a direct proportional relationship with speed of screw conveyor. Highest capacity of 19.12 kg/h was recorded at 19 rpm (Figure 5a and b). A non - significant trend was found between the throughput capacity and the temperature. It was also noticed that lower capacities were recorded at lower temperatures.

Effect of temperature, speed and treatment on conveyance efficiency

The results from the tests indicated that the conveyance efficiency of the machine reduced as the temperature increased. The highest conveyance efficiency 81.47% of the machine was obtained at the lowest temperature of 200°C and the lowest was obtained at 19 rpm and at 350°C temperature (Figure 6a and b). The trend showed a continuous reduction in machine's conveyance efficiency with increase in temperature

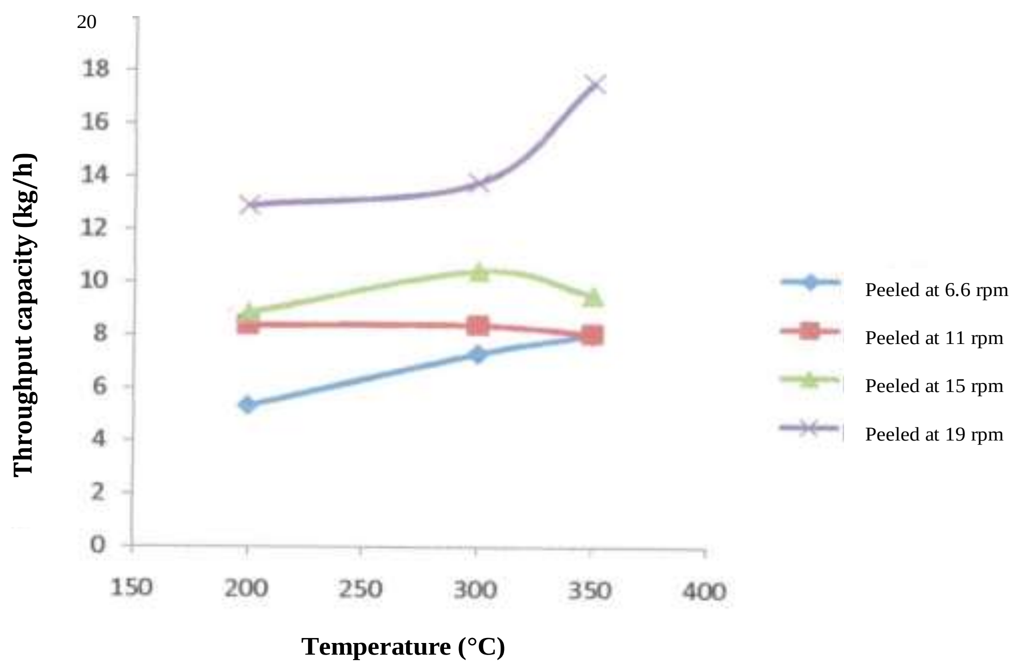

Figure 5b: Effect of temperature, speed and treatment on throughput capacity.

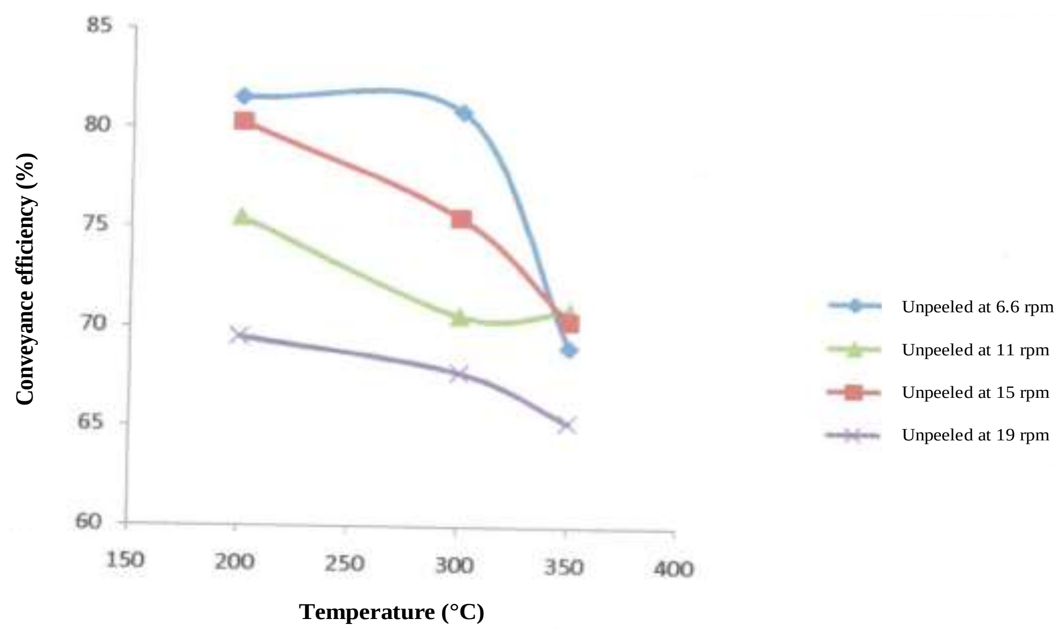

Figure 6a: Effects of temperature, speed and treatment on conveyance efficiency.

and speed.

Effects of temperature, speed and treatment on roasting efficiency

Roasting efficiency from Figure 7 shows a similar reduction trend as does the conveyance efficiency. For all tests carried out, conveyance efficiency reduces as temperature increases and also as the speed increases. This is an inversely proportional relationship between speed, roasting efficiency and temperature (Figure 7a and b); it can be given mathematically as:

$$T \propto \frac{1}{R.E} \qquad (4)$$

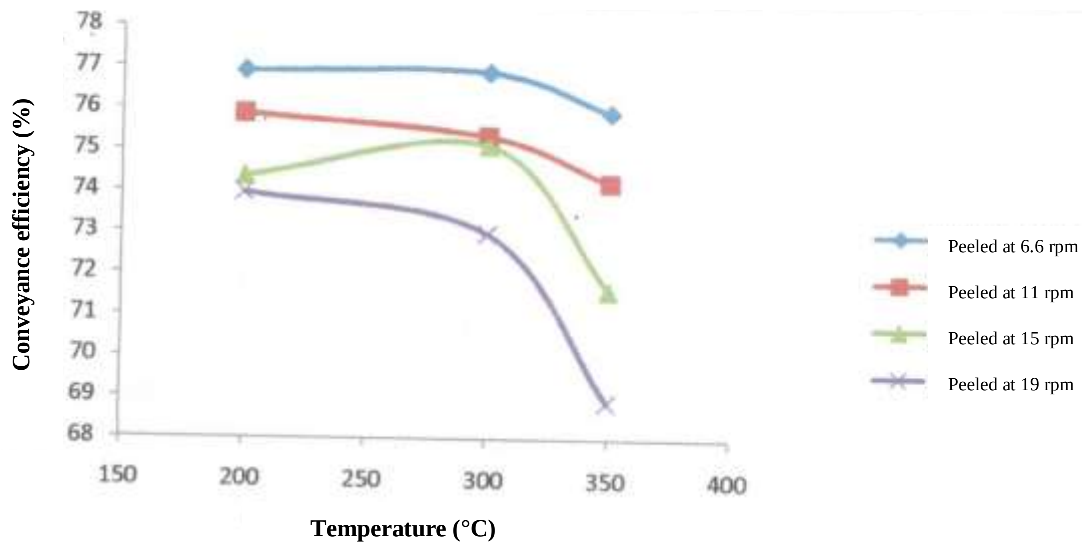

Figure 6b: Effects of temperature, speed and treatment on conveyance efficiency.

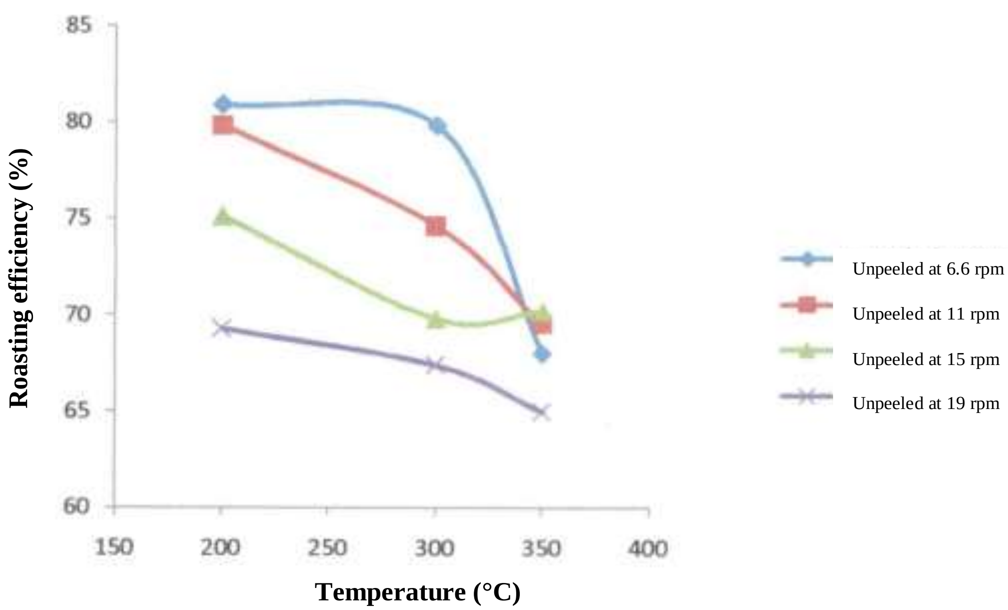

Figure 7a: Effects of temperature, speed and treatment on roasting efficiency.

Where:

T = Temperature;
R.E = Roasting efficiency.

$$S \propto \frac{1}{R.E} \quad (5)$$

This indicates that optimum performance can only be derived at low speed and temperature as the highest R. E. of 80.9% was derived at 200°C and at 6.6 rpm. The peeled kernels were also observed to have lower roasting efficiencies than the unpeeled at every tests carried out.

Effects of temperature, speed and treatment on roasting time

The time taken for maize to come out of the chamber was found to be reduced as the speed of screw conveyor increases. Also, peeled maize spent higher duration in the roasting chamber before coming out. The highest time taken 8.57 s was recorded at 200 rpm and the lowest duration of 2.04 min was recorded at 19 rpm for unpeeled maize kernels (Figure 8a and b).

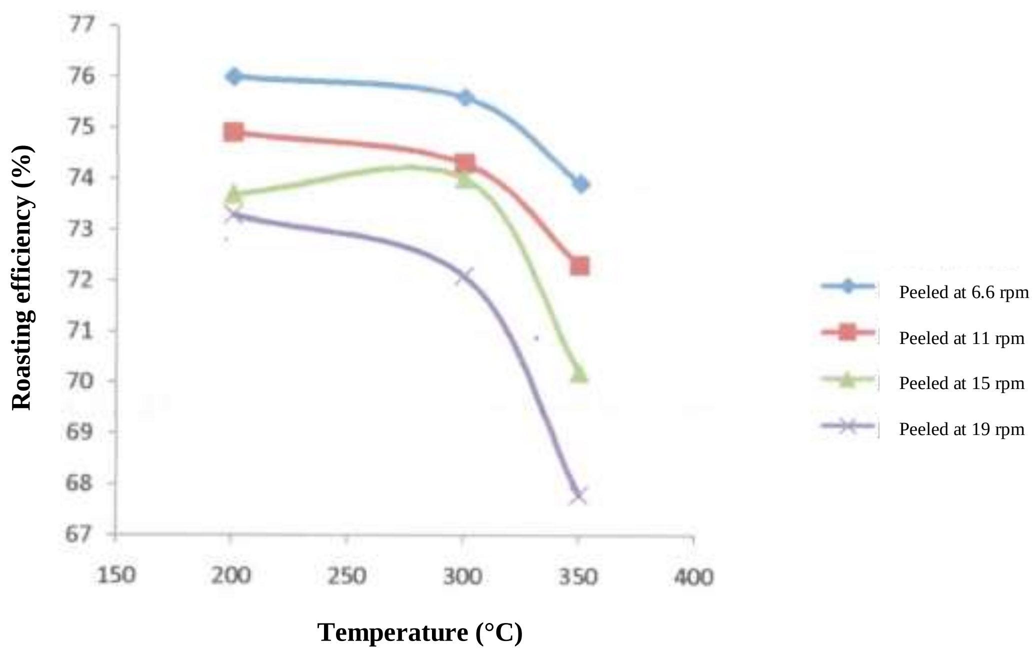

Figure 7b: Effects of temperature, speed and treatment on roasting efficiency.

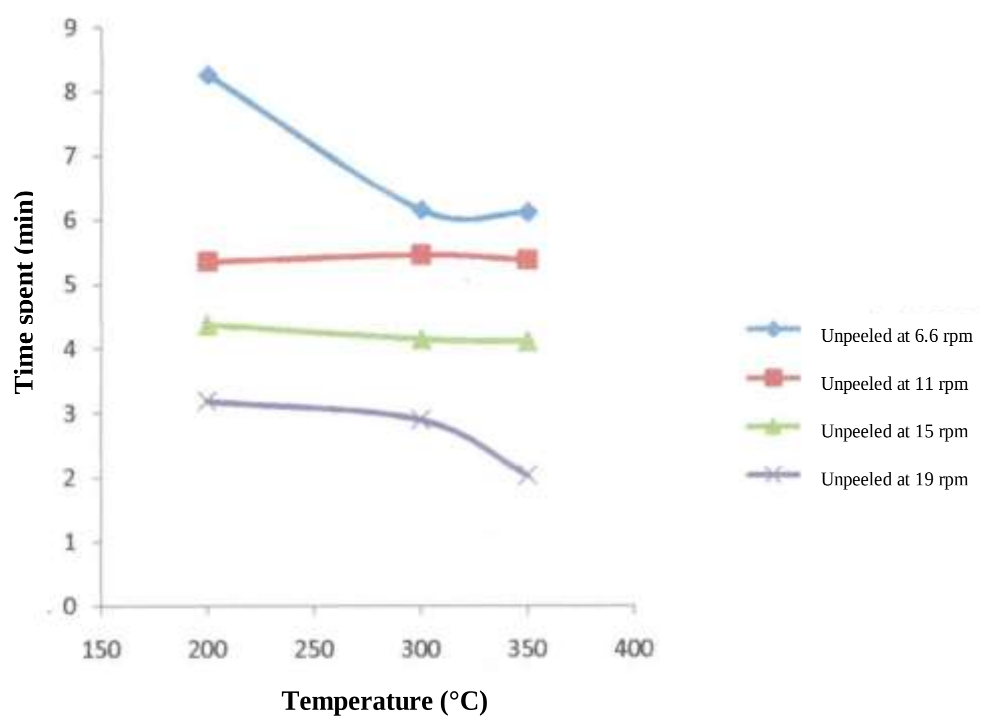

Figure 8a: Effects of temperature, speed and treatment on roasting time.

DISCUSSIONS

The machine exhibited maximum efficiencies at the lowest speed tested (200 rpm). The conveyance efficiency of the machine was low at temperature higher than 200°C and 6.6 rpms as nearly 20% of the materials are retained in the machine. This can be explained to be caused by thermal expansion that occurs on the roasting chamber as temperature becomes too high thereby causing the conveyor to pick few grains per time. Also, at higher speeds, the conveyor picks few grains leaving some in the roasting chamber. An optimum performance of the machine was however obtained

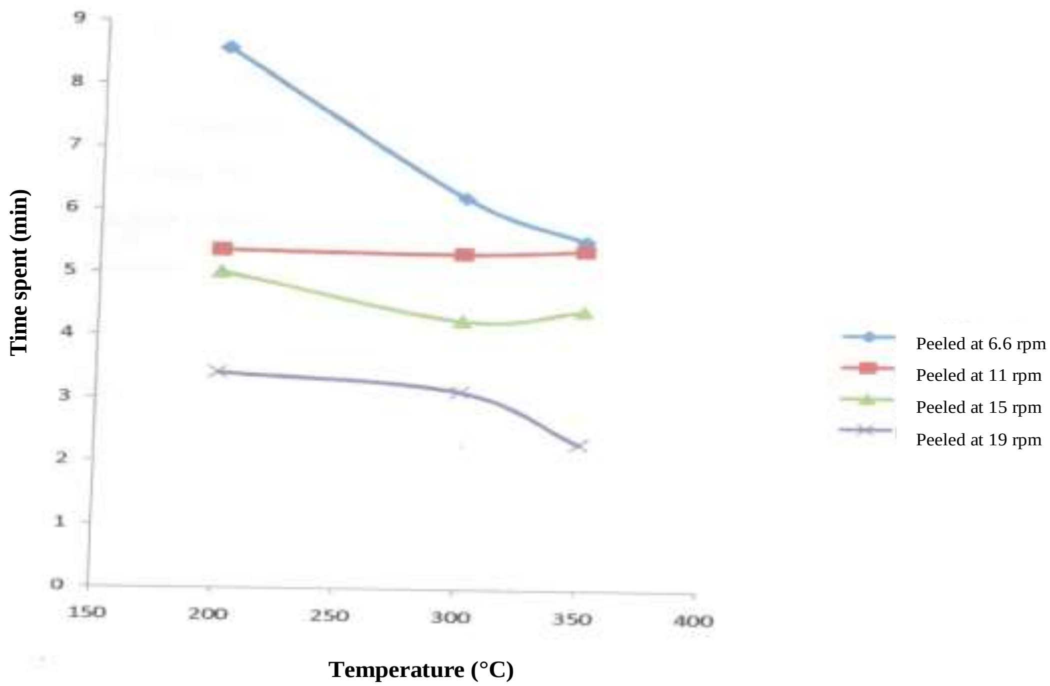

Figure 8b: Effects of temperature, speed and treatment on roasting time.

at 200°C and 6.6 rpm speed of the conveyor.

Conclusion

At the end of the experiment, 1000 g of unpeeled maize processed at 200, 300 and 350°C temperature at the same speed of 6.6 rpm, recorded a conveyance efficiency of 81.47, 80.76 and 69.02%, respectively. It can be concluded that as temperature increases, the conveyance efficiency also reduces at the same speed. At 200, 300 and 350°C temperature at the same speed of 11 rpm, conveyance efficiency recorded were 80.28, 75.35 and 70.30%, respectively. Concerning 15 and 19 rpm, similar trend was recorded.

The highest roasting efficiency recorded was 80.9% at the temperature of 200°C and speed of 6.6 rpm. For the peeled maize treatment, the highest conveyance efficiency was 76.84% at the speed 6.6 rpm and temperature of 200°C, while the roasting efficiency was 76% at speed of 6.6 rpm and 200°C temperature.

It can therefore be concluded from the experiment that as the temperature increases, the conveyance efficiency decreases; this could be as a result of thermal expansion of the material used in the roasting chamber. The temperature at 200°C with the speed of 6.6 rpm shows optimum performance of the machine.

Recommendation

The conveyance means should be improved in order to reduce the quantity of maize retained in the chamber. Roasting should only be carried out between 200 and 300°C, respectively in order to achieve good roasting.

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