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Review Article

Design of Automated Microcontroller Based System for Groundnut Oil Extraction

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Abstract: This research work, aims at mitigating the manual and low yield approach of the local system groundnut oil extraction which generally affects both the quantity and quality of the extracted oil. During the course of this research, studies were carried out on groundnut oil extraction which revealed that the optimum temperature for groundnut oil extraction is 90°C. This temperature at the preparatory heating chamber was properly controlled in this task by adopting an automation technique in which PID based microcontroller was deployed. A model of preparatory heating chamber and a PID controller were developed and deplored. The models were validated through a simulation process by varying the temperature parameters of the PID controller in order to achieve a desirable transient response of the system. After several simulations, a set of optimal parameters were obtained that exhibited a commendable improvement was achieved, thus improving the robustness and stability of the system.

Keywords: Groundnut oil extraction, Oil extraction, Manual extraction, Low yield, Optimum temperature.

INTRODUCTION

Groundnut seed (*Arachis hypogea*), which is common known as peanut, is one the most common oil nut grown as an annual crop in tropical, sub-tropical and warm temperature regions of the world. The process of its oil extraction in most developing nations especially in Africa is usually done manually by hand and like all other manual operations, it is laborious and time consuming. In a research publication by Lawan I *et al.*, (2015), it states that the oil content of groundnut is up to 50% (although the usual range is 40-45%) and 25-30% protein. Oil is extracted from groundnut through either traditional means (mostly dependent on human energy with about 20-30% of oil extracted) or mechanical means (over 90% of the oil can be extracted). Most vegetable oil is recovered by grinding, cooking, expelling and pressing or by solvent extraction of the raw materials (Ajav, 2011).

The most common method of extracting edible oil from oil seeds is by mechanically crushing and pressing of the oil seed (Bamgboye, 2007). Traditionally, groundnut oil extraction involves shelling the groundnut pods, roasting the shelled groundnut seeds, de-skinning/winnowing the roasted groundnut seeds, milling the cleaned groundnut seeds and kneading the paste produced (Lawal, Ali *et al.*, 2015).

Afterward, the crushed mass is mixed with water and the oil is obtained by cooking the mixture, causing the oil to float. The oil is finally skimmed off and dried by heating. The weak point of these processes are grating or crushing steps, they are time consuming and drudgery, yet crushing is generally not fine enough. Thorough crushing and roasting / heating can improve the oil recovery considerably (Emami and Watkins, 2009).

Background of the Study

The local roasting of groundnut produces uneven roast and this tends to affect both the quality and quantity of oil extracted. It is a tedious process involving hand stirring and exposure to heat. Manual groundnut roasters with stirrer have being constructed but a temperature regulatory device is still not inculcated because these roasters are powered by means of wood or charcoal. (Dorf and Robert, 2001).

The automated groundnut oil extractor system which this research proposes is aimed at removing drudgery involved at every stage of groundnut oil extraction and also improves both the quantity and

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quality of groundnut oil extracted. This is achieved by adopting automation (microcontroller based) technique in which PID controller was implemented to regulate the temperature at the preparatory heating chamber of the system to a desired temperature in the shortest possible time thereby improving the robustness and stability of the system.

Existing Physical System

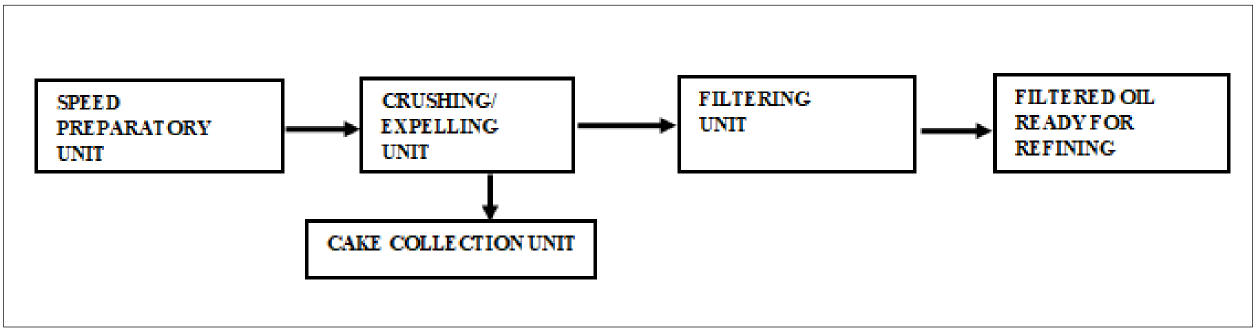

Figure 1: Existing physical system of groundnut oil Extraction System

Aim and Objectives

The aim of this work is to model a groundnut oil extraction system with improved yield through a full automation mechanism in which PID controller is implemented in microcontroller. The specific objectives include:

- The introduction of precision sensors for the preparatory heating chamber temperature regulation and weight monitoring.
- To develop a microcontroller based system model which are made up of the PID controller, the actuator and preparatory heating chamber.
- Determine the optimum preparatory chamber temperature which produces the best oil yield.
- To simulate and validate the developed model in order to determine the PID temperature controller parameters that gave a more optimum yield.

Review of Previous Literature on Groundnut Oil Extraction Systems

According to Ewaoda *et al*., (2008), processing or extracting or expressing oil from groundnut involves a wide range of traditional, mechanical, chemical and mechano-chemical methods. In their opinion, Ajao *et al*., (2010) opined that the traditional method involves roasting and crushing the groundnuts into fine particles, after which the crushed mass is mixed with water and boiled so as to allow the oil to float. The oil is then skimmed off and dried by heating. This method is time consuming, labour intensive, low output and low efficiency with lots of drudgery.

Asiedu (1989) explained that the mechanical methods involve the use of screw and hydraulic presses. The screw press is more reliable than the hydraulic press, but is slower and produces less pressure. The hydraulic press is more expensive, needs more maintenance and risk contaminating the oil with poisonous hydraulic fluid.

Generally, the mechanical methods have relatively higher operating cost than the traditional methods; however, they have higher efficiencies and are usually more adaptable for small and medium scale producers (Olayanju *et al*., 2004).

According to Maduako *et al*., (2006), the various modem methods of processing are predominant in developed countries while the manual processing is still the norm in many developing countries despite the drudgery and low output.

The author Olaniyan *et al*., (2012) carried out a research on the design, development and testing of a screw press expeller for palm kernel and soybean oil extraction. While designing the machine, consideration included: high oil yield, high extraction efficiency, low extraction, quality of oil, availability and cost of construction materials.

Design Methodology

In order to achieve the aim, a number of steps were taken such as:

- To design the temperature and weight sensors
- Design of the PID microcontroller based algorithm for system
- Simulation of the preparatory heating chamber for temperature stability

The Proposed System Block Diagram

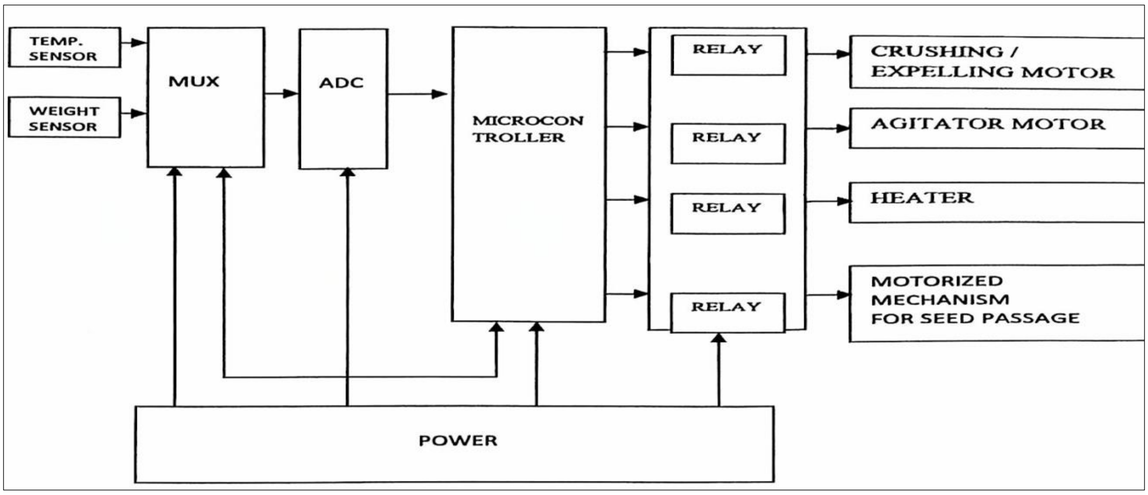

Figure 2: Block Diagram of the Proposed Groundnut Extraction System

According to the proposed system block diagram of figure 2 above, the system is made up of two sensors, they are: Temperature sensor (LM 35) and weight sensor (piezoelectric crystal). The temperature sensor senses the temperature of the preparatory heating chamber while the weight sensor senses the weight of the groundnut seed in the chamber. The 2-input to 1-output time multiplexer selects the input that goes to the microcontroller via ADC at any given time. The ADC converts the analogue voltage signal from the sensors to an 8-bit binary code which goes to the microcontroller for comparison using embedded algorithm.

There are two (2) variables that are required by the microcontroller. They are: Actual input, that is, chamber current temperature and desired set-point. The process variable is compared with the set-point of 90°C. If the actual value does not match with the set-point, the microcontroller generates an output signal which is the difference between the set-point and process variable. The output signal either activate or deactivate the actuator, that is, the relay to either put ON/OFF the respective elements such as heater, agitator motor, crusher and motorized opening mechanism for seed passage.

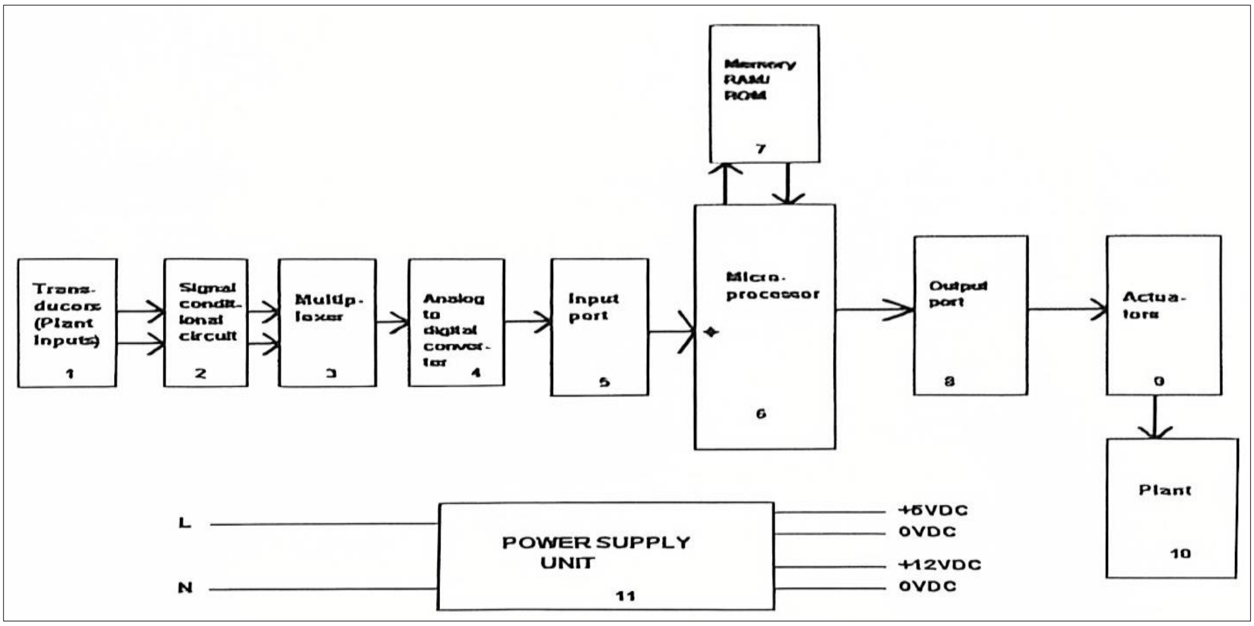

Figure 3: Detailed system block diagram

Subsystem Design/Modeling

The temperature control of the system was built on mathematical models needed for the analysis of the system dynamics, the design and evaluation of the control system. Figure 4 below, shows the closed loop structure of a preparatory heating chamber temperature controlled system. In this structure, the models of the system dynamics; sensors, actuators and computational effects are the basic elements which often cannot be altered. The design and fine tuning of the PID controller will be the subject of the analysis. A robust model will be developed and the system will be validated by simulating the controller model with the plant model, sensor and actuators or any combination of these components. The system is expected to track and/or regulate the desired preparatory chamber temperature with minimum peak time, rise time, settling time and overshoot.

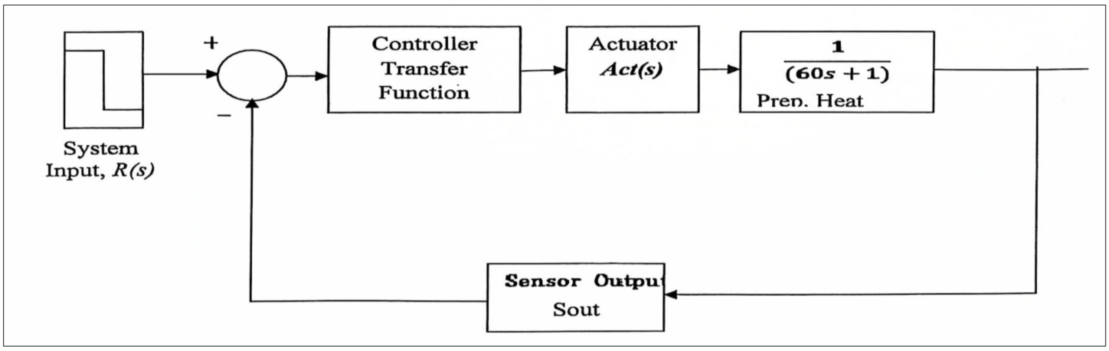

Figure 4: Block Diagram of the Closed Loop Temperature Control System

System Operations

Essentially, the two parameters being monitored by the proposed system are temperature and weight and each has a sensor. The operation of the system is based on a PID controller implemented on a microcontroller and temperature sensor. The temperature sensor senses the temperature of the preparatory heating chamber and converts change in temperature to electrical signal which is first converted to digital signal before it goes to the microcontroller. Here the microcontroller processes the data based on its embedded algorithm and sends a control signal to the respective port of the microcontroller. A pulse-width modulation (PWM) output from the controller is used to drive a relay for switching ON/OFF of the required load which could be heater, agitator motor or crusher.

On the other hand, when the weight of the groundnut seed being monitored by the sensor gets to zero, a control signal is sent to the output port of the microcontroller for closing of the motorized seed passage opening.

Algorithm- *Algorithm for automated microcontroller based system for Groundnut Oil Extraction.*
Input: *Temp, Weight, Process 1, Process 2*
Output: *Agitator/Stirrer Motor, Crusher/Expeller Motor, Heater, Motorized opener for seed passage*
Begin (): *Set Gain*
C Set Batch
C Process 1, Process 2
C Process 1
1 Start Heater
Start Temp test until
IF Temp ≥ 90°C
Stop Heater
Else
IF Temp < 90°C
GOTO 1
STOP
END
C Process 2
Start Motorized Seed Passage
1 Start Crusher/Expeller Motor
Start weight test
IF Weight = 0kg
Close Motorized Seed Passage
Else
GOTO 1
STOP
END.

Simulations and Results
Experimental Investigation

The effects of heating temperature and heating time on the yield and quality of extracted oil were investigated with the aim of identifying and regulating the temperature at the optimum yield using a microcontroller based PID controller.

Effect of Temperature Variation on the System Output (Oil Yield)

The table 1, shows temperature variation in the heating chamber of the groundnut oil extracting system for a 4kg/hr capacity of machine according to Yusuf *et al*., (2014) and Olatunde *et al*., (2014)

Table 1: Effect of temperature and heating time variations on the percentage of oil yield

Preparatory Chamber Temperature (^{0}C)	Percentage of Oil yield (%)	Heating Time (Minutes)
70	19.50	10
80	22.80	20
90	24.40	25
100	23.90	30
110	22.40	35

Source: (Yusuf *et al*., 2014)

The experiment revealed that the oil yield increases with increase in heating temperature but tends to decrease as the temperature increase from 90°C to 110°C. Increasing heating temperature to a highest value of 90°C and a heating time of 25 minutes increased the percentage of oil yield to a value of 24.40% which is an equivalent of 92% when compared to 45% oil content of groundnut (Olatunde *et al*., 2014). The increased heating temperature and time also improved the colour intensity of the oil expelled which agrees with the finding on groundnut by (Ajibola *et al*., 1990). The expression efficiency is approximately 92% when compared to the 45% oil content of groundnut.

The colour of oil extracted was observed to be affected by the heating time and heating temperature as confirmed by (Makeri *et al*., 2011). Thus no substantial increase was observed in the percentage of oil yield beyond 90°C, this is in correlation with the findings of (Ajibola *et al*., 1990).

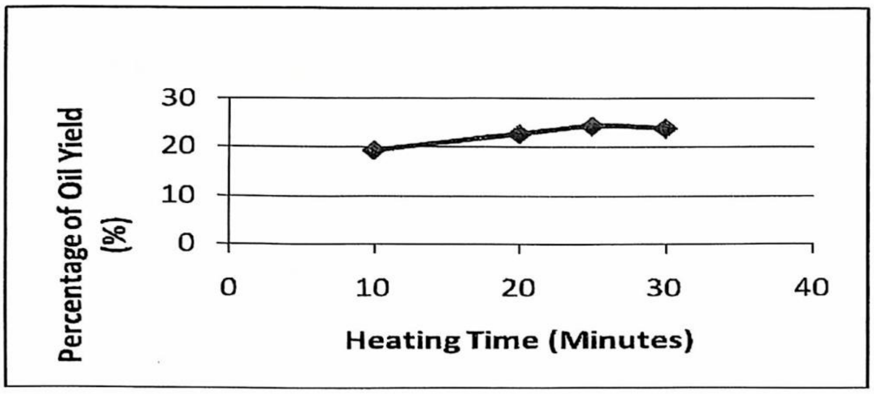

Figure 5: Plot of Heating Time against percentage of Oil Yield

Result Analysis

The Matlab/Simulink was used for the system analysis, various parameters were tested and the best parameters were used for PID implementation on the microcontroller. It was observed from the results obtained that the optimal set of parameters that gave a more desirable yield at 90°C. However, when the temperature was increased beyond 90°C, the expected yield reduced.

Hence, a PID algorithm implemented on a microcontroller, simulated and fine-tuned using the set of parameters obtained will exhibit a better control performance by maintaining the temperature conditions in the groundnut oil extraction preparatory chamber at 90°C as clearly shown in figure 6 and 7 for the non-stabilized and stabilized temperature chamber respectively.

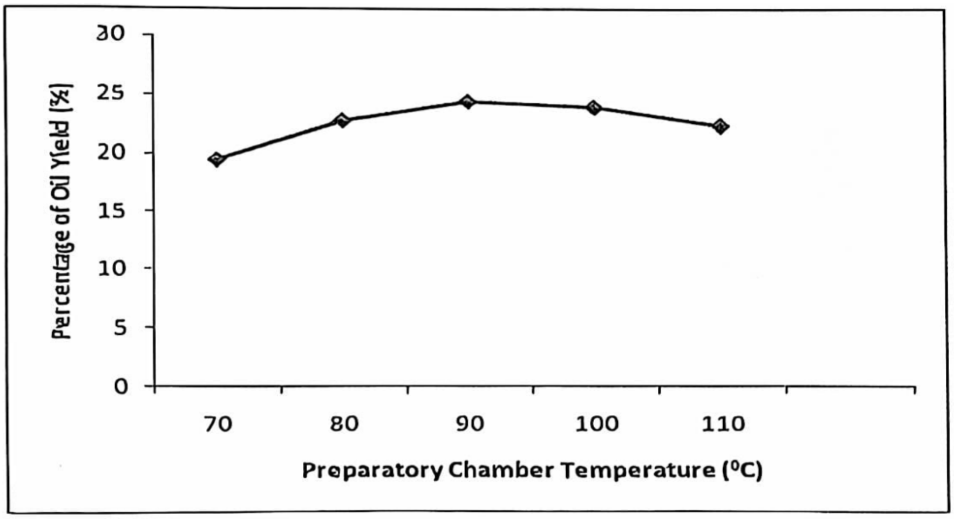

Figure 6: Non-stabilized preparatory Chamber Temperature

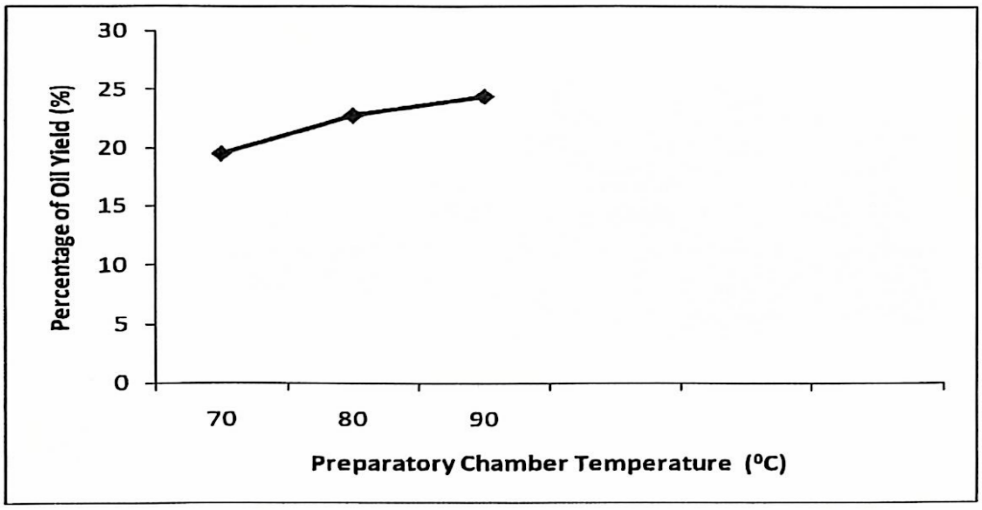

Figure 7: Graph of percentage of oil yield against preparatory Chamber Temperature for the stabilized chamber

CONCLUSION

This research, automated microcontroller based system for groundnut oil extraction as it seeks to improve on the effect of poor and irregular heating that existed in the traditional system which often leads to low oil quality and quantity, will help a long way in maximizing the quality and quantity of groundnut oil production and also ensuring minimal human involvement as the system is fully automated.

PID controller implemented in microcontroller was used to ensure temperature stability (90°C) at the preparatory chamber of the proposed system for groundnut oil extraction. The essence of this was to address the irregular heating effect of the traditional system which has always gave rise to waste due to low quality and quantity of oil extracted.

Mathematical models of the preparatory chamber, Actuator and PID controller were developed. PID controller gain/temperature control parameters for obtaining closed loop stability were tuned, After several simulations attempt, a set of optimal parameters were obtained that exhibited a commendable improvement in the overshoot, rise time, peak time and settling time thus improving the robustness and stability of the system.

Contribution to Knowledge

This research has made the following contributions:

It has provided a means of stabilizing temperature in small scale industrial processes. Some applicable industries include but not limited to vegetable oil processing/extraction, incubation system, ventilation system and many more.

Suggestion for Further Improvements

The use of alternative processor architectures and other programmable logic devices such as FPGAs/CPLDs should be explored for groundnut/vegetable oil extraction system design. This will make it applicable for wide range of small scale industrial applications.

In addition, future research can be done in the area of microcontroller design for multiple input-output systems with special emphasis on multivariable feedback control applications and robust performance for other similar plants.

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