PROCESSING OF *KAYA* USING JACKETED MIXER WITH MICROCONTROLLER

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ABSTRACT

A computerized system was set-up on a pre-fabricated and manually-controlled jacketed mixer for data acquisition and controlling convenience during the processing of kaya. A microcontroller board which contains a popular microcontroller, PIC16F876A (Microchip Technology Inc.) was developed. A software program associated with the board was written using Microsoft Visual Basic 6.0 for interfacing involving parallel port programming. The C-code of microcontroller was written using Microsoft Visual C++ that compiles C-code into Hex code for downloading into the flash of microcontroller via downloader software. Upon successful development of the hardware and software of the microcontroller board, investigations on behaviour of kaya were performed. Experiments were conducted at three levels of temperatures in the range of 60ºC to 80ºC and four levels of paddle rotation speeds in the range of 20 to 50 rpm. A Brookfield DV-II+ Viscometer was used to measure the viscosity of kaya during processing and at the end of cooking. The cooking of kaya was most suitable at 70 ºC and 50 rpm giving a kaya viscosity of about 270 cP, similar to the industrial practice. Using Power Law model, a stress-strain relationship of kaya showed that it possesses a pseudoplastic behaviour.

Keywords: *microcontroller, kaya, Power Law Model, pseudoplastic*

INTRODUCTION

Coconut Jam or more popularly known as '*Kaya*' is a famous Asian jam spread used in breads and confectioneries. *Kaya* is a jam made from coconuts and eggs, flavoured by the unique pandan leaf, and sweetened with sugar. It originated in Hainan, China, and is now popular in Malaysia and Singapore [1]. It tastes sweet and somewhat creamy, and is available as either a green or brown colored spread, depending on the amount of pandan added.

Kaya is processed by mixing cum cooking under indirect heat and occasional stirring. The cooking process from liquid mixture to *kaya* paste takes up at least two to three hours. *Kaya* is simply made by mixing three main ingredients, which are coconut milk, eggs and sugar at an appropriate ratio. Permitted amount of food colour, flavour and conditioner could be added to enhance the taste of *kaya*.

The processing of *kaya* must be monitored under a tight supervision due to its variation in product properties because of slight difference in processing procedures. Changes in properties such as viscosities and cooking temperature will result in easy spoilage of *kaya*. Thus, it is relevant that an automation system being set up to monitor and control the operation of the *kaya*-maker machine to ensure consistency in its output. Convenience of data collection and centered controlling provide easy and accurate monitoring of *kaya* consistency and quality during processing. These allow studies to find its optimum processing condition.

MATERIALS AND METHODS

2.1 Microcontroller Hardware Development

Figure 1 shows a block diagram of the system set up. It consists of three main parts, the controller board, personal computer and the *kaya*-maker machine. The objective of this project is to interface the machine control from the existing control panel to automated PC program controlled. Therefore a micro-controller board is fabricated to fulfill this objective.

The existing control panel of the *kaya*-maker machine consists of three hardware controllers that include speed controller (inverter), temperature controller and timer. To allow interfacing to PC, the temperature controller and timer will be bypassed. These two controllers will be replaced with micro-controller chip programmed to serve the same functions. The inverter that controls speed of the motor rotation will remain but to allow interfacing, some modifications are done to it including the parameter settings and usage of additional relays for voltage control. The Microcontroller hardware is divided into three parts:

- **Microcontroller Board** which includes Microchip PIC16F876A, 7 Relays, RS232 Module, and Thermocouple Amplifier as the main components.
- ***Kaya*-Maker Machine Set ups** which includes the Inverter, Contactor and Thermocouple as the main components.
- **Personal Computer Set ups** which includes the DB-9 Parallel Port Adapter as a main component.

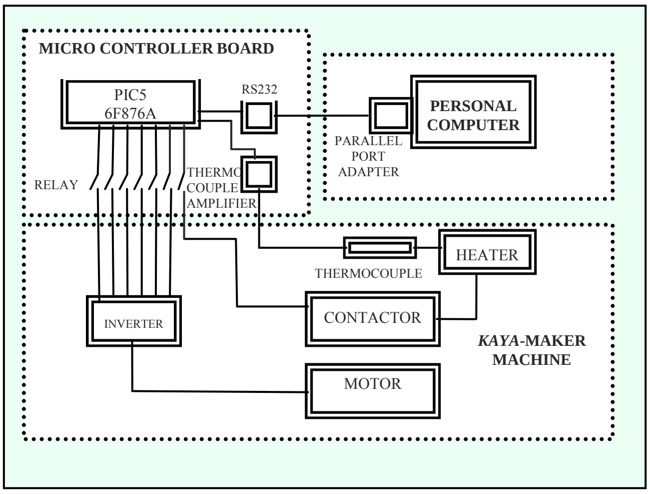

Figure 1: A Block Diagram for the Microcontroller Hardware

2.1 Microcontroller Software Development

Figure 2 shows the process flow of the software developed to control the *kaya*-maker machine using three processing parameters, *i.e.* cooking temperature and time and paddle speed. The operations are as described:

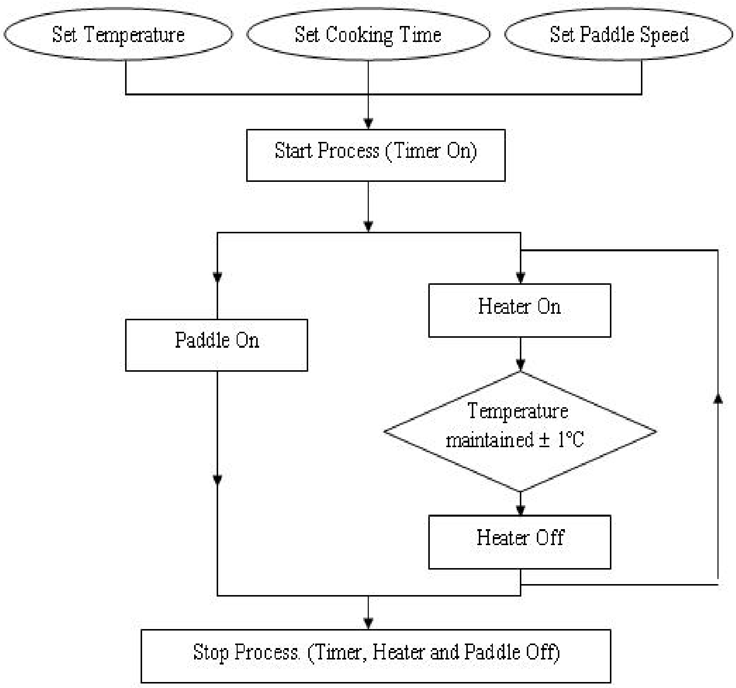

Figure 2: Flow Chart of Machine Control Software Description

- The program allows soft timer to set desired period for cooking and upon engaging the start button, the timer starts a time countdown.
- Paddle speed will be controlled by the program. An initial speed is set to the paddle, and the program allows increments and decrements to the speed. The paddle begins rotating once the timer starts and stop once the timer terminates.
- Desired cooking temperature is input and the program ensures the temperature is maintained at a ± 1ºC. If temperature exceeds the set point temperature by 1ºC, the heater will be turned off. Where else if the temperature drops 1ºC below the set point, the heater turns on automatically. The temperature sensor is a thermocouple; data collected from the sensor goes through calibration before the current temperature of the *kaya* is displayed. This ensures more even display of temperature without too frequent fluctuation of the display. The sensor collects few data at a short interval time to calculate an average equivalent temperature before displaying on the interface program.

2.2.1 Programming Using Visual Basic 6.0

Since the parallel port is employed as the interface link to the controller board, its corresponding parallel port programming is done using Visual Basic. Visual Basic 6.0 was used as it offers flexible, powerful, visual and event-driven programming language, that one can easily build a Graphical User Interface (GUI). It is user-friendly and has all the features needed to write a small program. It was used to write the software for the controller board with parallel port.

2.2.2 Microcontroller Programming Using Microsoft Visual C++ 6.0

Microsoft Visual C++ is the software where the source code of PIC16F876A microcontroller is written in C-Code. It is also C-Compiler, which compiles C-Code and generates Hex file to be downloaded into the microcontroller, via the constructed downloader circuit.

2.2.3 Downloading Program Using WinPic800

Having done with programming the microcontroller using Microsoft Visual C++, the Hex files generated earlier was downloaded into the microcontroller. This was done using WinPic800 which is a simple yet powerful serial device.

2.3 **Kaya** *Materials and Experimental Levels*

Materials used in the experiments to produce *kaya* are eggs, sugar and coconut milk as formulated according to Table 1. The eggs used were obtained from local market with average weight of 57.0 gram. The egg white and egg yolk composition is 89% [2], therefore the liquid egg from one piece of whole egg is approximately 50.7 gram. As formulated, the amount of liquid eggs needed was 250.0 gram. Four to six pieces of eggs yielding 250.0 gram liquid eggs were used in the experiment. The sugar used was obtained from local market and refined sugar was chosen to allow smooth texture of the *kaya* produced. The coconut milk used was also bought fresh from the local market.

Table 1 *Kaya* Formulation

Ingredients	Part	Weight (g)	%
Liquid Eggs	1.0	250.0	25.00
Sugar	1.5	375.0	37.50
Coconut Milk	1.5	375.0	37.50
TOTAL	4.0	1000.0	100.0

Table 2 Experimental levels of variables

Variables	Levels	Values
Temperature, T (ºC)	3	60, 70, 80
Speed, N (rpm)	4	20, 30, 40, 50

Table 2 summarizes the experimental levels planned for three processing parameters. Temperature indicates applying three different temperatures for *kaya* cooking. Speed indicates applying four different speeds for agitator rotation in the experiments. *Kaya* cooking time was 120 minutes for all the experiments.

2.4 Consistency Measurements of Kaya

Kaya cooking was performed at three different temperatures and four paddle rotation speeds. During the cooking process, the consistency of *kaya* at interval time of 10 minutes was measured as viscosity using a Brookfield DV-II+ Viscometer. Spindle selection was made according to the range of percent torque readable from the viscometer display. Only percent torque within the value 10-100% is acceptable according to Brookfield Operating Instruction Manual. RV spindles were selected for the measurements as they are the most recommended spindles for food products with medium viscosity and that exhibits non-Newtonian behaviour such as dairy products, gums, creams and so on. The data obtained from the viscometer readings were viscosity (in units of centipoises, cP or milliPascal-seconds, mPa·s) and % torque. The % torque was multiplied with a conversion factor of 7187.0 dyne-centimeters (full scale), specified by the manufacturer of the Brookfield for RV model, then divided by 100 in order to obtain an actual torque in units of [dyne*cm] (Equation 1). 1 dyne·cm is equal to $1x10^{-7}$ Newton meter. (in units of dyne-centimeters or Newton-meters, both shown as percent, %).

$$\text{Actual Torque, T} = \frac{(\%torque) * (7187.0)[dyne \cdot cm]}{100} \qquad (1)$$

2.5 Characterization of Kaya Product

The final cooked *kaya* product, for 120 minutes from every experiment was subjected to shear stress versus shear rate analysis. Shear stress values were calculated from the torque values following Ozdemir and Sadikoglu (1998) [3] as given in Equation 2:

$$\text{Shear Stress, } \tau = \frac{T \ [dyne \cdot cm]}{2\pi \cdot L \ [cm] \ R^2 \ [cm^2]} \qquad (2)$$

where
L = Effective length of spindle [cm]
R = Radius of spindle [cm]
T = Actual torque [dyne·cm]

The shear rate, γ, in [rpm] was taken from the different spindle rotational rate used on selected spindle in Brookfield DV-II+ Viscometer [3]. The power law model, also known as the Ostwald Waele model, $\tau = K \cdot \gamma^n$, where τ is the shear stress expressed in Pa, γ is the shear rate in s^{-1}, n is the flow behavior index, and K is the consistency index in $Pa \cdot s^n$, [4] was used to fit experimental data and the flow characteristic of *kaya* was calculated.

RESULTS AND DISCUSSIONS

3.1 Viscosity of Kaya during Processing

Figures 3 to 5 show the viscosity-time curves of *kaya* cooked at three temperatures, 60ºC, 70ºC and 80ºC and at four paddle rotation speeds, 20, 30, 40 and 50 rpm. The purpose of this plotting is to monitor the changes of *kaya* flow behaviour during cooking which is from a viscous mixture into paste-like jam. The best final viscosity of *kaya* after 120 minutes of cooking is about 270cP as recommended by industrialist [7]. Figure 4 shows that *kaya* produced at 70ºC and at 50 rpm had a viscosity closest to 270 cP.

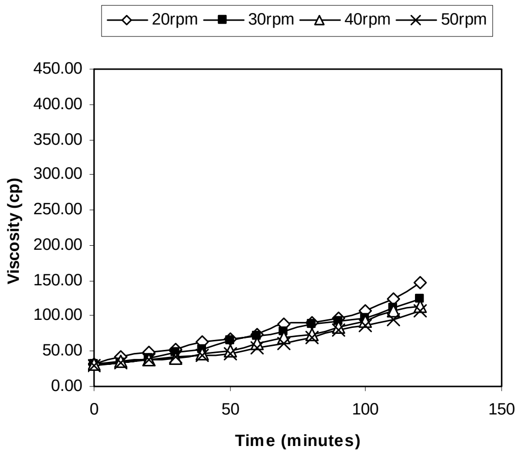

Figure 3: Viscosity versus time at cooking temperature of 60°C and at four paddle speeds (N = 20, 30, 40 and 50 rpm)

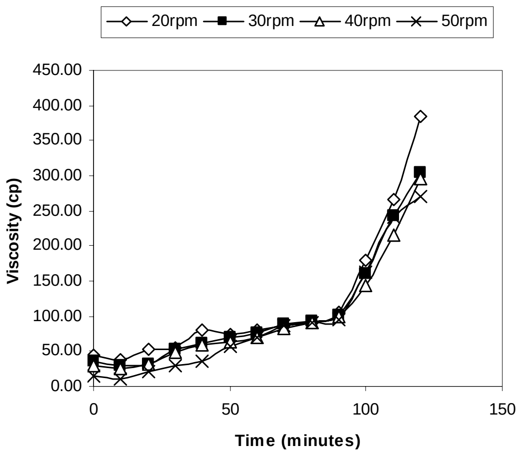

Figure 4: Viscosity versus time at cooking temperature of 70°C and at four paddle speeds (N = 20, 30, 40 and 50 rpm)

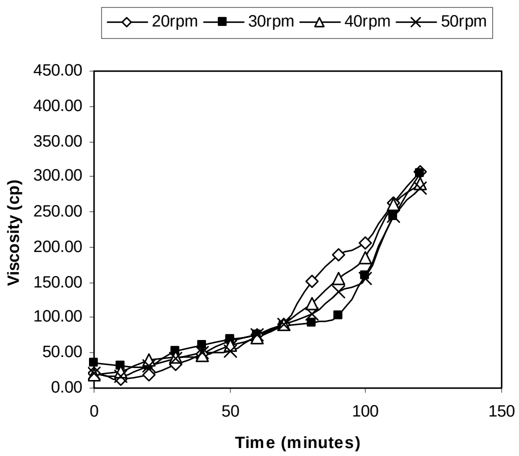

Figure 5: Viscosity versus time at cooking temperature of 80°C and at four paddle speeds (N = 20, 30, 40 and 50 rpm)

3.1 Stress-strain Analysis of Kaya

Figures 6 to 8 show the stress-strain curves of *kaya* cooked at different paddle rotation speeds of 20, 30, 40 and 50 rpm at three temperatures, 60ºC, 70ºC and 80ºC. All *kaya* products regardless of its cooking temperatures and paddle rotation speeds showed an increase in shear stress, τ, with increasing shear rate, γ. From the typical curves of dependence of the shear stress on shear rate, *kaya* shows a non-Newtonian behaviour and posses a pseudoplastic behaviour. Few researchers have studied the rheological behaviour of different kinds of jams [5] and practically in all the cases; a non-newtonian and pseudoplastic behaviour was displayed. A marked change was also observed in the *kaya* with increasing temperature. Higher temperature of 80°C yielded *kaya* with higher shear stress values compared to those at 60°C and 70°C.

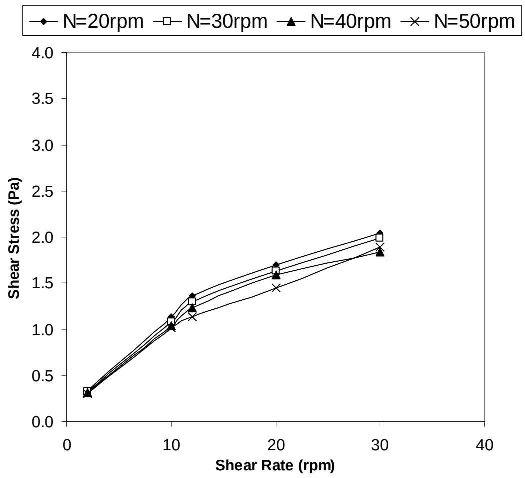

Figure 6 : Stress versus strain of cooked kaya at 60°C and at four paddle speeds (N = 20, 30,40 and 50 rpm)

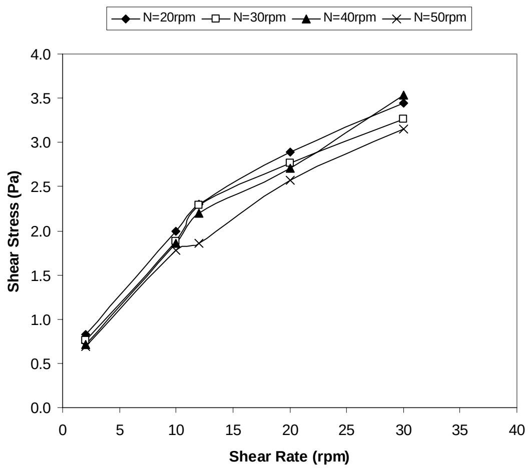

Figure 7 : Stress versus strain of cooked kaya at 70°C and at four paddle speeds (N = 20, 30,40 and 50 rpm)

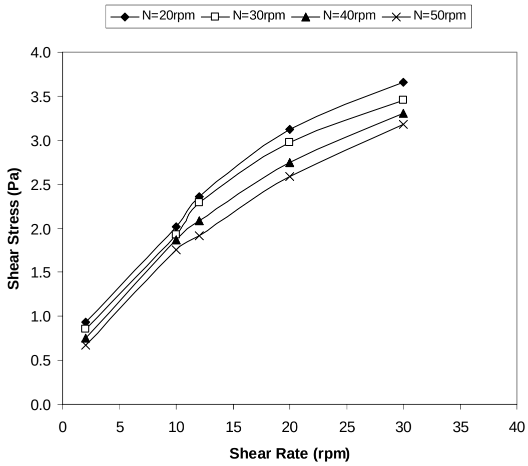

Figure 8 : Stress versus strain of cooked kaya at 80°C and at four paddle speeds (N = 20, 30, 40 and 50 rpm)

The flow behaviour index, *n,* obtained from plots of logarithm shear stress versus logarithm shear rate are from 0.51-0.68, confirming its pseudoplasticity (shear thinning) behaviour [6]. The best *kaya* produced at 270 cP using temperature at 70ºC and paddle rotation speed of 50 rpm produced a product with behaviour index of 0.5645 in the Power Law Model Equation, $\tau = (0.4683)\,(\gamma)^{0.5645}$.

Table 3: Behaviour index, *n* of *kaya* cooked at three temperatures and four paddle rotation speeds

N (rpm)	**Temperature, T (°C)**		
	60	70	80
20	0.6773	0.5328	0.5153
30	0.6808	0.5510	0.5292
40	0.6827	0.5717	0.5549
50	0.6844	0.5845	0.5775

CONCLUSIONS

The development of microcontroller board for the *kaya*-maker machine has facilitated data acquisition and control of *kaya* quality during processing. The microcontroller board allows controlling of three essential processing parameters, cooking temperature, time and paddle rotation speed. These allowed *kaya* cooking to be done consistently versus the manually operated cooking style. With the help of this computerized system, tedious human interaction with machine control panel manually and human errors was minimized during the conduct of experiment to study *kaya*. Precision and consistency are also sought. These features can be implanted into larger scales manufacturing machines in industry for consistency and precision purposes.

The overall changes in *kaya* flow behavior were observed. Suitable operating temperature of 70ºC and spindle rotation speed of 50 rpm produced *kaya* of good quality, *i.e.* with consistency of about 270centipoise (showing slight lumpiness) as claimed by the industry [7]. *Kaya* cooked at 60ºC did not exhibit any lumpiness at all and its texture is much smoother compared to those cooked at 70ºC and 80ºC. This is because the egg whites and yolks only begins to coagulate at 62ºC and 65ºC respectively [8]. It is therefore not advisable to cook *kaya* at temperatures below the coagulation of egg because *kaya* may not be completely cooked and this may cause food poisoning due to active microorganisms in liquid egg. Lumpiness in *kaya* cooked at temperature higher than 60ºC is acceptable as a mouthfeel property.

Technically, *kaya* shows a flow characteristic of a pseudoplastic or shear thinning material. The increase of shear stress with shear rate of *kaya* cooked at all temperatures and paddle rotation speeds gave a behaviour index of 0.51-0.68 falling in the range of $0<n<1$ for pseudoplastic material. *Kaya* produced at the condition of temperature 70ºC and paddle rotation speed of 50 rpm gave a behaviour index of 0.5645.

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NOMENCLATURE

τ	Shear Stress	(Pa)
γ	Shear Rate	(s^{-1} or rpm)
μ	Viscosity	(cP)
K	Consistency Index in Power Law Model	($Pa \cdot s^{n}$)
n	Flow Behaviour Index in Power Law Model	(dimensionless)
N	Paddle Rotation Speed	(rpm)