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Deployment of an Electronic-based Approach for Fruits Juice Ingredient Analysis

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Abstract - *This paper considers the deployment of an electronic-based fruits juice ingredient analysis. Most of the fruits juice products available in the market now contain water in large quantities than the active ingredients. This design attempts to respond to the end user's complaints. By putting on this design, it is expected to serve as a quality check and control for our teeming enterprising fruit substance producers. The system was designed and simulated using proteus and implemented using hardware electronic components. The system uses an infrared transmitter, fruit sample handler, and infrared receiver to realize its design. The instrument was calibrated with natural pineapple juice with 60% of water content. The outputs of this device were displayed using a cathode ray oscilloscope and voltmeter respectively. Five different samples of fruit juice were analyzed namely: A, B, C, D, and E. Results showed that all fruit juice contains a reasonable quantity of water which is not regarded as an adulteration since it is the natural content of the fruit. However, water content above 60% may be considered as much. It is recommended that fruit juice producers employ this system for their quality and control checks. Moreover, further research should take into consideration, the colour and viscosity of different fruit juices with a view to seeing how the system can analyze them, while the output should incorporate a microcontroller for an intelligent analysis and digital display.*

Keywords: Fruit Ingredient, Infrared Transmitter, Infrared Receiver, Sample Handler and Analyzer

I INTRODUCTION

Fruits are essential food needed by humans for healthy living as they contain micronutrients namely, vitamins and minerals which help in the prevention of various diseases [1-3]. The consumption of fruits has increased rapidly in the last three decades which has led to the demand for high-quality products and an increase in the number of fruit-juice-producing industries [4, 5]. However, the quality of the products needs to be checked and controlled in order to increase the product value and competition among producers [6, 7]. In this paper, an electronic-based fruits juice analytical model was developed and deployed for checking the ingredient to water content in five common fruits namely; A, B, C, D, and E.

The electronic-based fruit juice analytical model uses an Infrared transmitter as the source of light, a fruit container to demonstrate the fruit specimen, and an Infrared receiver that receives the light intensity from the transmitter via the varying samples. In this design, if the sample contains 100% of water, the receiver will seem not to output any signal. This is because the light intensity has been completely absorbed by Water. However, if the sample contains 0% of water the receiver will output a full signal with a little loss, showing that this fruit juice contains almost 100% of the fruit ingredients.

Figure 1 demonstrates Beer Lambert's law which states that the amount of light intensity absorbed or transmitted by a sample is proportional to its molar absorptivity and concentration [8-10].

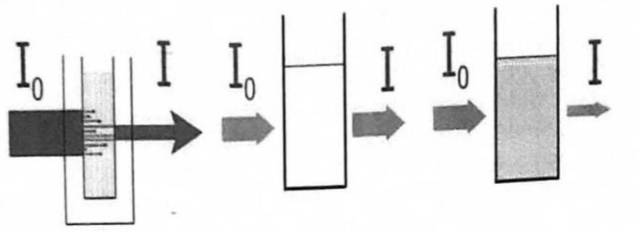


Figure 1: Incident and transmitted light on fruit Samples

In other words, if the intensity of the incident light is higher than the intensity of the light received, then there is some level of absorption within the sample. However, if the two intensities: that of the received light is I, the transmittance T, of the system is given by *Io* are equal

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then, there is no light absorption. The transmittance of the incident light is given by

$$T = \frac{I}{I_o} \quad (1)$$

Such that the system's absorbance A will be given by

$$A = -log_{10}T \quad (2)$$

The gradient of the absorbance and samples concentration gives the absorptivity of the system. Infrared signal was chosen because of its property of being easily absorbed by clearwater [11, 12]. This makes it possible to detect the presence of water in any given sample of liquid using light energy. This concept is the idea behind absorption spectroscopy.

The purpose of this paper is to design and implement an electronic-based fruits juice ingredient analytical model. The model was achieved using the following objectives: to design a suitable Infrared light transmitting circuit; to design a suitable Infrared light detection circuit, to determine a suitable fruit handler (cuvette) that permits the light rays to pass through, to design a suitable signal conditioning circuit and to evaluate and analyzed different fruits substances with the designed circuit and make necessary recommendations.

[13] considered eleven (11) samples of white yoghurts in the experiment of absorptivity of light using near, middle and far Infrared spectroscopy. The wave number used was 10270 cm^{-1}. This was to determine the actual water content of the yoghurt samples. The result of the study shows that the water present in the 11 white yoghurts samples was determined. Several methods were used, though the oven drying method proved to be most accurate thus, it was used as the reference to other methods.

In another research work, [14] it was established that the water content of fruits can be determined through direct and indirect methods. In the direct method, physical separation techniques such as distillation, drying and chemical reaction were employed. In the indirect method, spectroscopy was employed; in which case nuclear molecular resonance (NMR), Raman spectroscopy and Infrared came into play. Among other methods used, the Near Infrared (NIR) spectroscopy was able to adduce that the colour, particle size, thickness and texture of the sample, affect result. Therefore, these factors must be seriously considered in such studies.

Recently, [15] carried out an interesting study to show that Infrared radiation is not only used for mixture absorption but can also be used for drying food substances. Prickly pear (*opuntia Ficus Indica*) products were used for the study. From the result of the experiment, a relationship was established between the variation of shrinkage of the product and its water content. Effective diffusion coefficient of water transfer was determined using the Fick law at three drying temperatures namely 40°C, 50°C, and 60°C. Thus, the Infrared radiation was successfully used to dry prickly pear.

[16] also worked on infrared drying technique. In the study, six methods of water determination were explored for the purpose of drying bee pollen samples. The methods were: conventional oven drying at 100°C, vacuum oven drying at 70°C, desiccator with sulfuric acid, drying out process with infrared light at 85C, lyophilization and Karl Fisher's method. The result reveals that the best methods for water determination of the bee pollen were the drying process with infrared and the lyophilization.

Another study to confirm that temperature has an effect on infrared radiation was carried out by [17]. It was proved that measurement of fruit constituents NIRS technology has become suitable at all stages of food production from the purchase of raw materials and ingredients to the control of the finished products. In the end, it was buttressed that Infrared radiation has a serious relationship with hydrogen bonding and ambient temperature.

[18] went rather further in his work by implementing the function of Near Infrared (NIR) spectroscopy in the analysis of meat, fruit, grain, dairy products and beverages. Another exercise included experiments on online measurement of data, chemo-metric treatment, as well as interpretation of the experimental data [19].

A Fourier Transform Infrared (FTIR) technique has significant potential as a quantitative quality control tool for the food manufacturers. FTIR analysis methods are suitable, rapid and automatable, and in combination with attenuated total reflectance (ATR) probe technology, dramatically simplifies absorption analysis. The main elements of FTIR spectroscopy are presented along with a selection of methods under development, including analyses of milk, meats, fats and oils, butter, sweetened condensed milk and juices. The FTIR provides clear evidence of the benefits in quality control applications [20]. In addition to food substances, Infrared spectroscopy can find its application in pharmacy for the purpose of analyzing the active ingredients of drugs.

Some related studies by eminent researchers, reveals that their design did not deviate from the underlying principle of Infrared spectroscopy which uses Infrared transmitter and receiver circuits for the analysis of the samples, while the output was displayed on the Cathode Ray Oscilloscope. This is a departure from the traditional display format of spectra which other works mentioned above, made use of. The intention is to enable the user know the exact level of concentration of the ingredients of the friut substance. This design is a bit different from the ones reviewed above, especially in the aspect of the display. This design serves as quality control check instrument for the fast-increasing small and medium scale enterprising firms springing up in the country. It is locally designed, easy to use and low-cost as compared to the imported spectroscopy systems. It can readily find its applications in such small enterprises as yoghurt, fruit juice, milk, wine, pomade, paint, and sachet water production firms. In educational institutions where there is need for the study of light, the spectroscope can be used to really appreciate the dispersion of light into a spectrum. The spectral display would make the study of light more real than it is read from textbooks. This design can be adopted as laboratory equipment in several laboratories.

II RESEARCH METHODOLOGY

A. Materials

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The materials used to realize this design include: Infrared LED (GaAs TSTS7100); Infrared receiver (BPW24R silicon pin photodiode) Wavelength, = 0.9; 555 timer IC; Resistors; Capacitors; Q2N2222A transistors; 741 operational amplifiers; Cuvette and food samples.

B. Methods

The design was reduced to blocks for the realization of the final device. The production of the device actually followed the logical arrangement of the blocks. However, the actual schematic circuit that was implemented is shown in the next section. Figure 2 is the block diagram of the device that realized the design.

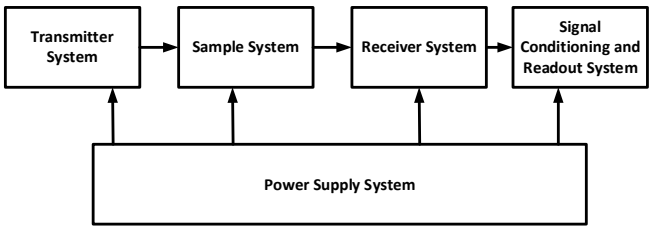


Figure 2: Block diagram of Electronic-based Fruits juice Ingredient Analytical Model

The following are the blocks and their constituent components: the transmitter system: This system consists of infrared LED, 555 timer IC, resistors, capacitors and transistor. Sample system: This system is made up of the cuvette and the specimen to be sampled. The specimen sample includes A, B, C, D and E. The receiver system: This system consists of an Operational amplifier, resistor and Infrared receiver. The signal conditioning and readout system: This system consists of operational amplifier, resistors and cathode ray oscilloscope. The power supply system: This consists of a dual power supply system to service the operational amplifier and the single supply aspect service the other components.

C. Mathematical Design Model

One subsystem that requires serious mathematical exercise is the transmitter unit. The main active component here is the 555 timer IC. This IC was configured in the astable multivibrator mode. The most interesting property of this type of multivibrator is the Time Constant denoted with T and given by frequency is the reciprocal of time and is given by

$$T = 0.69(R_1 + 2R_2)C \quad (3)$$

Frequency is the reciprocal of time and is given by

$$F = \frac{1}{T} \quad (4)$$

$$F = \frac{1}{0.69(R_1+2R_2)C} \quad (5)$$

A fixed resistor R_1 was selected to be 1KΩ and the variable resistor RV_2 to 10KΩ, with the DC voltage supply of 15V with a 10µF capacitor.

The RV_2 resistor was varied until the desired pulses were determined:

$$F = \frac{1.44}{(R_1 + 2R_2)C} = \frac{1.44}{(1 + 2 \times 10)\text{K}\Omega \times 10\mu F} = 6.86Hz$$

The 555 timer Ic generates pulse signal with the capacitor C chosen as 10uF. The switching was achieved with an NPN transistor number Q2N2222A whose function is to prevent the 555 timer lc from maximum sink and possible damage. From the light Emitting Diode (LED) datasheet, the forward current (I_f) was 250mA and the forward bias voltage at 250mA given by (V_f) is 1.7V.

Therefore, the value of the limiting resistor is given by

$$R_2 = \frac{V_{cc} - V_f - V_{be}}{I_c} \quad (6)$$

$$R_2 = \frac{15 - 1.7 - 2.6}{0.25} = 42.6\Omega$$

Transistor gain of 30 was considered.

$$h_{fe} = \frac{i_c}{i_b} \quad (7)$$

The above modelling led to the determination of the values of the components so considered in the transmitting circuit. The duty cycle of the signal was approximately 50%. In the signal detection circuit, the silicon pin photodiode (BPW24R) was used as the Infrared sensor and resistor 5MΩ was used as the feedback resistor of the 741 Operational amplifiers. The output voltage was derived from (9) with a very small amplitude.

$$V_{out} = -I_{in}R \quad (9)$$

This amplification stage was cascaded with a second stage amplifier with input resistor, R_{in} of 10KΩ and feedback resistor R_f of 330KΩ. This second stage of amplification led to the determination of the amplifier gain for this design.

$$Gain = -\frac{R_f}{R_{in}} \quad (10)$$

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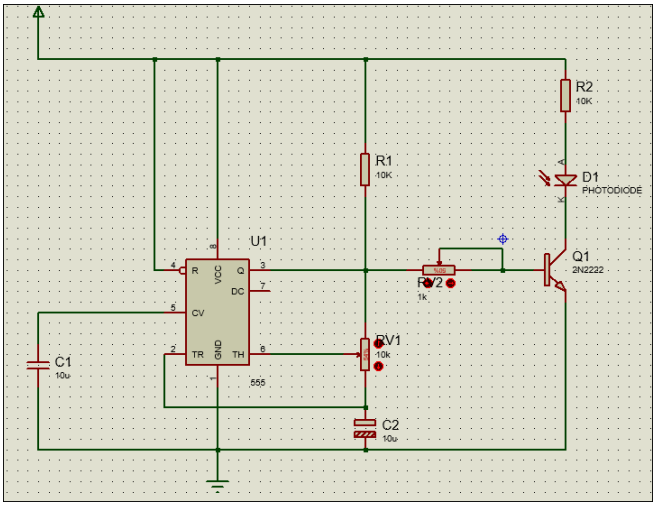


Figure 3: Transmitting Circuit Diagram of Electronics-based Fruit Juice Ingredient Analytical Model

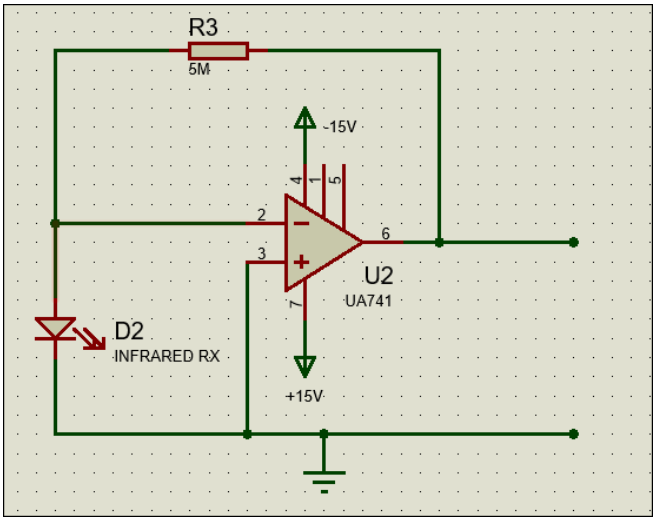


Figure 4: Receiving Circuit Diagram of Electronics-based Fruit Juice Ingredient Analytical Model

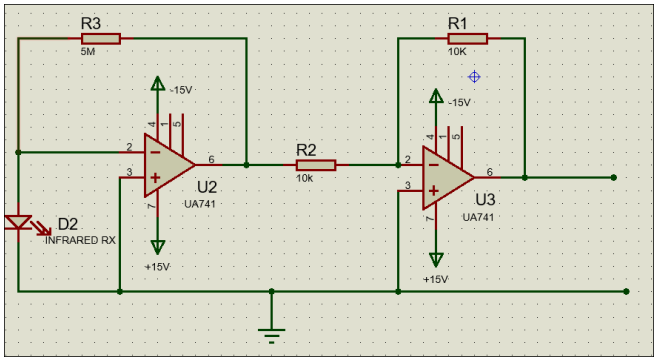


Figure 5: Signal Conditioning Circuit for Electronics-based Fruit Juice Ingredient Analytical Model

D. Pre-Calibration Considerations

The system voltage representing the light intensity is 5V meaning this measurement will consider 0 - 5V and the water content of the fruit juice uses the scale of 100% that is 0 - 100%.

Scaling and the calibration assumption is given by the expression

V = Voltage (i.e., signal intensity)

P = Percentage of water in the sample

(0 - 5)V = (0 - 100)%

$V_1\ V_2 = P_1\ P_2$

According to cartesian coordinate rule and scaling rules

5V = 100P

$P = \frac{100}{5} = 20V$

$P = 20V_1$

E. The Hardware Design Calibration

The system voltage representing the light intensity is 5V meaning that this measurement considers 0 - 5V and the water content of the fruit juice uses the scale of 100%. The natural pineapple juice used in this demonstration showed a water content of 60%. This means that if the system is to discriminate against water content of below or above 60% the scaling should take the form of 60 - 100%.

F. Scaling and the calibration assumption given by the expression

V = Voltage intensity

P = Percentage of water in the sample

(0 - 5)V = (60 - 100)%

$V_1\ V_2 \qquad P_1\ P_2$

According to Cartesian coordinate rule and scaling rules

$$\frac{V - V_1}{V_2 - V} = \frac{P - P_1}{P_2 - P} \tag{11}$$

$$\frac{V\ -\ 0}{5\ -\ V} = \frac{P\ -\ 60}{100\ -\ P}$$

$$\frac{V}{5\ -\ V} = \frac{P\ -\ 60}{100\ -\ P}$$

V(100 - P) = (5 - V)(P - 60)

100V - VP = 5P - 300 - VP + 60V

Collecting like terms

40V - 5P = -300

40V = 5P – 300

$$V = \frac{5P\ -\ 300}{40}$$

$$V = \frac{P\ -\ 60}{8}$$

$$P = 8V + 60$$

G. The Procedural Test Approach

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i. The device was connected to the power supply.

ii. The whole setup was switched ON.

iii. The natural pineapple fruit was squeezed until the juice came out and it was used to fill the sample cuvette.

iv. The sample cuvette containing the natural juice was placed in the space provided in the sample handler. The change in the light intensity was read and recorded using a voltmeter as shown in Table 1.2. This was used for calibration.

v. Another sample of pineapple juice was poured into the cuvette and placed in the sample handler.

vi. The light intensity was read and recorded using voltmeter as shown in Table 1.3. This is the first measurement after calibration of the device.

vii. Steps (V) and (VI) were repeated for the other four fruits juice samples namely: A, B, C, D, and E.

H. Model Implementation

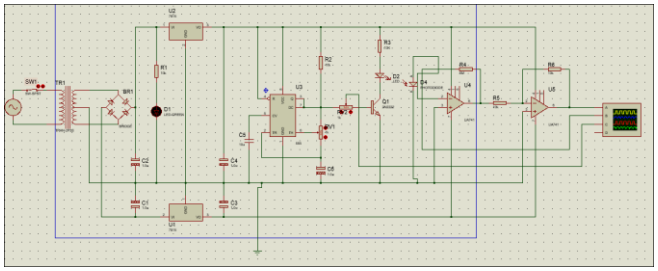


Figure 6: Complete Circuit diagram of Electronic-based Fruit Juice Ingredient Analytical Model

In figure 3 and 4 , the transmitter section of the circuit was realized using 555 timer IC configured in the astable multivibrator mode. R_1, RV_2 and C_1 form the RC oscillator network used to determine the frequency and duty cycle of the signal generated by the timer. The output signal leaves through pin 3 of the IC and is used to bias transistor Q1 through RV1. Infrared LED D_1 releases the output signal as an invisible signal towards photodiode. This received signal, which is usually weak, is then conditioned by way of amplification using Operational amplifier 741 cascaded in two stages. The output signal was displayed on an oscilloscope and a voltmeter. In between D_1 and D_2 is a sample handier which carries a cuvette containing fruit juice sample. The incident signal was always made to pass through the fruit juice sample. If the water content of the sample is 100%, the incident signal is completely absorbed by the sample and so, no signal reaches the photodiode D_2. As a result, the signal intensity on the display device tends towards zero. On the other hand, if the water content of the sample is 0%, the entire incident signal passes through and be received by the photodiode, thereby giving an output voltage value of 5V as signal intensity. Therefore, as the percentage of the water content of the fruit juice varies between 0 - 100%, the signal intensity also varies accordingly.

III RESULTS AND DISCUSSIONS

A. Software Simulation Result

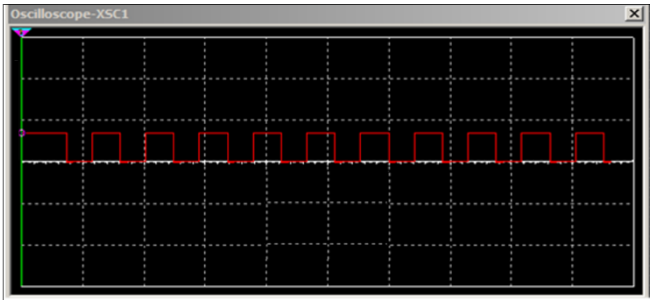


Figure 7: Transmitting Circuit result of Electronic-based Fruit Juice Ingredient Analytical Model

Figure 7 is the output waveform of the transmitting circuit as presented in figure 3. The waveform is a continuous pulse signal with duty cycle of almost 50% and the signal is then transmitted to the receiver system.

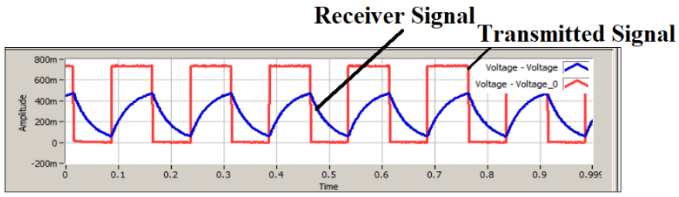


Figure 8: Output Waveform of the Receiver System

Figure 8 is the output waveform of the developed device. The simulation model from the receiver's system in figure 4 is conditioned in figure 5. The signal was displayed on the Cathode Ray Oscilloscope in Figure 6. The signal had undergone conditioning and thus, affected its shape.

B. Pre-calibration Result

Table 1.1: Pre-calibration Result

Serial Number	Percentage Water (P)	Voltage Intensity (V)
1	0	5
2	10	4.5
3	20	4
4	30	3.5
5	40	3
6	50	2.5
7	60	2
8	70	1.5

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9	80	1
10	90	0.5
11	100	0

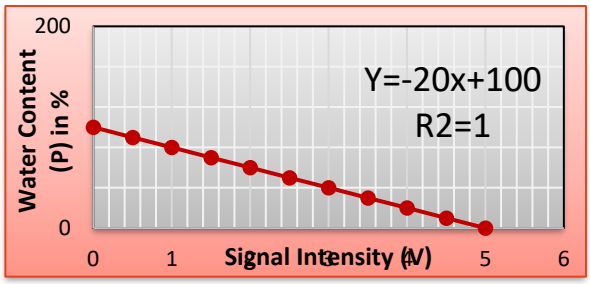


Figure 9: Pre-calibration graph for the Electronic-based Fruit Juice Ingredient Analytical Model

Table 1.1 and Figure 9 shows the pre-calibration assumption result obtained from simulation. This shows that in an ideal situation where the fruit juice has 100% ingredient and 0% water, the light intensity in voltage would be 5V. If the water content increases in steps of 10% the corresponding light intensity would be decreasing in steps of 0.5V.

C. The Hardware Design Calibration Result

The hardware design calibration was carried-out using natural pineapple juice with 60% of water. This was adopted as the threshold for the system calibration as presented in Table 1.2.

Table 1.2: Hardware design Calibration Result

Serial Number	**Percentage Moisture(P)**	**Voltage Intensity (V)**
1	60	5
2	64	4.5
3	68	4
4	72	3.5
5	76	3
6	80	2.5
7	84	2
8	88	1.5
9	92	1
10	96	0.5
11	100	0

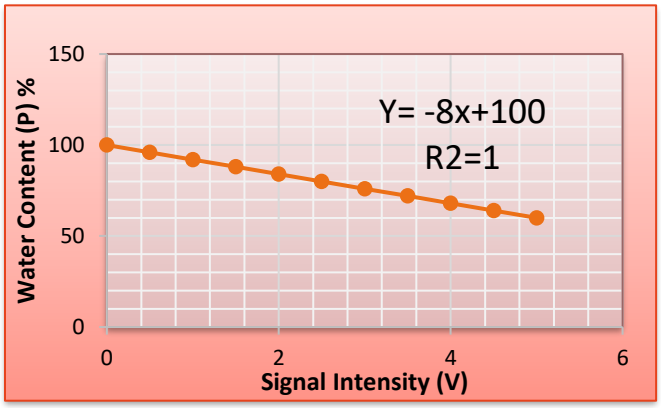


Figure 10: The calibration graph for the developed Fruit Juice Ingredient Analytical Model

Figure 10 present the graph of the water content of the sample fruit juice versus signal intensity produced by the samples. The graph shows the signal intensity produced by 60% of water content and above after calibration. This 60% of water content produced a corresponding signal intensity of 5V. This means that water contents of below 60% produces signal intensity of above 5V. This makes it easy to determine the fruit juice substance with much concentration of the ingredient and that with the water content above the threshold.

D. Hardware Design Result

Table 1.3: Hardware Design Result

Juice Samples	Water Content	Ingredient Content	Signal Intensity (V)
A	60	40	4.80
B	75	25	3.84
C	79	21	3.65
D	42	58	6.86
E	85	15	3.39

Table 1.3 shows the result gotten from the study, where the water contents, ingredient contents and signal intensity produced by the sample fruit juice used in this experiment (A, B, C, D and E).

The result reveals that the sample A had 60% water, 40% ingredient and produced light Intensity of 4.8v which is

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very close to that of the natural pineapple used in the calibration. Therefore, there was a slight absorbance of light intensity.

Sample B improved the workability of this device by showing the water content of 75%, ingredient content of 25%, and light intensity of 3.84V. The signal absorbance here was also low.

Sample C with water content of 79% and ingredient content of 21%, produced light intensity of 3.65V. The signal absorbance was a bit higher in this case.

Sample D recorded the lowest water content of 42% and highest ingredient content of 58%, hence yielding the highest light intensity of 6.86V. It recorded the highest ingredient content and signal intensity, as well as the least signal absorbance among all the sample fruit juice used in the study.

It was noted that sample E had the highest moisture content of 85% and least ingredient content of 15%, thus producing the least light intensity of 3.39V. This shows that the light intensity was almost completely absorbed. Therefore, it recorded the highest signal absorbance among all the sample fruit juice used.

IV CONCLUSION

The above-mentioned fruit juices were analyzed based on their ingredient water contents. This was achieved using the action of Infrared radiation which has been proven to be sensitive to water. Experimentally, the higher the water content in a substance, the more the Infrared light absorbed when made to pass through it. Again, this exercise validates the Beer Lambert's law which states that when a beam of light is made to pass through a sample solution, the level of light intensity absorbed varies directly with the water content of the sample and the path length of the light. Moreover, the results obtained in this paper should be taken as absolutely as it is purely an academic exercise not to devalue the fruit juice products by discussing their respective ingredient level. It does not also presuppose that any of the fruit juice analyzed here is substandard as they must have passed through regulatory bodies and certified for its standard obligations.

V RECOMMENDATIONS

This study did not take cognizance of the viscosity, colour, texture, density, weight, refractive index, and electrical conductivity of the sample analyzed. However, water content affects all these factors as well. The study only looked at the water content of liquid samples. It is therefore the opinion of this paper that other researchers research into designing a device that can analyze liquids, giving results of the level of the above-mentioned factors in the sample liquid under study. There should also be an incorporation of microcontroller for the purpose of intelligent analysis and digital display of results.

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