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Measurement of Sugar Concentration in Korean Commercial Coffee Drinks Using Portable Saccharimeters

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Abstract

The purpose of this work was to measure the concentration of the sugar contained in Korean coffee drinks by using portable saccharimeters. We also investigated the reactivity of three kinds of portable saccharimeters to Korean coffee drinks.

From these results, three kinds of the portable saccharimeters used in this experiment were useful for measuring the sugar content in the coffee products. And, we confirmed that the values obtained from these measurements have a statistically significant. And, we could be predicted the concentration of sugar (TDS) in unlabeled the coffee drinks by using the calibration curves obtained from this study.

Keywords: Sugar content, Saccharimeters, Korean coffee drinks, Calibration curve

INTRODUCTION

In recent, due to the influx of western culture in Korea, it has brought about many changes in the field of Korea's traditional food and culture. Among these changes, coffee drink has been become one of a best favorite beverage. And, various kinds of coffee products and a variety of coffee shops have been emerged here and there.

The effects of coffee on the human healthy has been studied by many researchers [1, 2]. But the sugar content in these products would have been a negative effect on teeth [3, 4, 5]. And many domestic and international researchers have been studied on the negative impact on the health of children [4, 6, 7].

The research to measure the sugar content in these drinks also have been performed by many researchers [8-11]. However, the determining the sugar content in product took a great deal of time and expensive equipment [5, 6, 7]. So, it did not allow the easy measurement at home and school.

However, in recent, there were a portable saccharimeters being released at an affordable price. These saccharimeters have a lot of advantage in such function with a high reproducibility and with a high convenience like as washable.

In this study, we tried to measure the sugar content in the Korean coffee products using saccharimeters which was purchased in Japan [12, 13, 14]. And, to determine what these apparatuses are measured, we set the assumed-value to compare with these values and the measured values. This comparison was important to ensure the accurate measurements. And it was important to verify the accuracy and reproducibility of these saccharimeters.

The purpose of this research was placed as follows:

1) To measure the sugar content in the Korean coffee products.
2) Check the correlation between the measured values.
3) To get a calibration curve by using the measured value and the assumed value.
4) To predict the sugar content in the unlabeled coffee by using the calibration curve.

EXPERIMENT METHOD

Experiment Equipment

The saccharimeters which was used in this experiment are three different types as below. The brief features of each equipment are as follows.

PAL-Coffee (BX/TDS): It is able to examine the sugar content of coffee and TDS (total dissolved solids: a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular) simultaneously.

PAL-J: The measurement range of Brix is 0.0-93.0%. Unlike the principle of general saccharimeter, it is not affected by other components and able to conduct accurate sugar content [13].

PAL-BX/RI: It has dual scales of Brix full range: Brix 0.0 to 93.0%, high measurement accuracy: Brix ±0.1% and refractive index (resolution 0.0001).

How to use the portable saccharimeters

Step 1. Use micro pipette to collect 300 microliters from sample and drop it on a prism of the apparatus.

Step 2. Push start button.

Step 3. Read Brix value.

Step 4. Repeat step 2 and step 3 for 5 times.

Table 1: Ingredients and contents indicated on labels of sample A

mL	Caffeine (mg)	Hydrocarbonate(g)	Sugar (g)	Protein (g)	Fat (g)	Saturate (g)	Trans-fat (g)	Cholesterol(mg)	Salt (mg)
200	103	20	20	3.8	2.4	1.4	0.0	5.0	85.00

RESULT AND DISCUSSION

Samples

The ingredients and contents of sample A (drink type: dairy drink, volume: 200ml) which was used in this experiment were described in <Table 1>.

In Korea, it has been forced to display the concentration of caffeine in the coffee because many types of coffee drinks contain caffeine. The display order of ingredient on label as follow as; content of hydrocarbonate, sugar, protein, fat (saturated fat, trans fat), cholesterol and sodium by g or % concentration.

Measurement Result

The expected values of sugar content could be obtained by recalculating the total amount of i) sugar or ii) carbohydrate or iii) total dissolved solid (TDS).

In case of sample A, we could be obtained the expected sugar content by converting the sugar content value (g and %) labeled on the product. The expected value of sugar content by this method was 10.0. And by converting the labeled carbohydrate value, we obtained the expected value of sugar content (10.0). And, by converting the labeled TDS content, we obtained the expected value of sugar content (13.2).

The measured values obtained from three different kind of portable saccharimeters used in this experiment were provided in <Table 2>. On three saccharimeters, the experimental values were all higher than the expected values (measurement value: 15.12~15.84). In the case of PAL-J, it showed 2.0 point higher than the expected value obtained by calculated from TDS.

We thought that the origin of difference between the expected and measured sugar contents are based on the lack of accuracy of measurement apparatus or labeled mark or a measurement interruption by another ingredient substances.

Table 2: Measured value of sugar content by using three different kinds of saccharimeters

	1st	**2nd**	**3rd**	**4th**	**5th**	**Ave.**
PAL-Coffee	15.11	15.15	15.20	15.20	15.19	**15.17**
PAL-J	15.80	15.80	15.80	15.90	15.90	**15.84**
PAL-BX/RI	15.20	15.10	15.10	15.10	15.10	**15.12**

Correlation coefficient of measured value of each saccharimeter

As shown in <Table 3>, the correlation of the measured values by three saccharimeters could be evaluated using the statistics program. According to the statistics analysis, there was a significant result among the measurement apparatus. In other words, there were slight differences between measured values, but they shared mutual dependability. Therefore, this result verified the credibility in measuring sugar content by any of three measurement tools used in this study.

Table 3: Correlation between measured values by three different types of saccharimeters (A: PAL-Coffee saccharimeter, B: PAL_J saccharimeter, C: PAL_BX/RI saccharimeter)

		A	B	C
A	Pearson correlation coefficient	1	.996**	.998**
	Probability		.000	.000
	N	25	25	25
B	Pearson correlation coefficient	.996**	1	995**
	Probability	.000		.000
	N	25	25	25
C	Pearson correlation coefficient	.998**	.995**	1
	Probability	.000	.000	
	N	25	25	25

Calibration curve

The other purpose of this study was to make calibration curve for saccharometers to predict the sugar content in coffee drink which was not clearly suggested the sugar content. Most of the commercial drink available in market have a sugar content abiding by the guideline of government, but some commercial drinks that are on sale in coffee shops or handmade products do not displaying the sugar content.

Therefore, the experiment was conducted targeting coffee drinks purchased at market to make calibration curve in accordance with sugar content. Then, based on the calibration curve obtained from the measurement, the sugar content of unlabeled samples was obtained.

<Table 4> provides 1) the recalculated carbohydrate unit, 2) sugar unit, and 3) total dissolved solids(TDS) unit. <Table 5> shows the measured values of 25 samples (one sample is a distilled water as reference).

Table 4: Expected value of sugar content by considering the concentration of carbohydrate, sugar, and TDS labeled in 25 samples, respectively

	mL	Carbohydrate	Sugars	TDS
Coffee1	200	12.5	11.5	14.3
Coffee2	200	10.0	10.0	13.2
Coffee3	240	9.6	8.8	12.8
Coffee4	240	9.6	8.8	12.8
Coffee5	240	10.0	8.3	11.7
Coffee6	270	9.3	8.9	11.8
Coffee7	200	9.0	9.0	11.7
Coffee8	275	9.1	8.7	10.8
Coffee9	270	8.9	7.8	10.2
Coffee10	200	8.5	8.5	10.2
Coffee11	275	8.7	8.7	10.0
Coffee12	240	8.8	7.5	9.5
Coffee13	200	7.5	7.5	8.9
Coffee14	275	6.5	6.9	8.5
Coffee15	200	6.5	6.5	8.5
Coffee16	200	4.5	4.5	5.1
Coffee17	150	4.7	4.7	4.7
Coffee18	200	4.5	4.0	4.5
Coffee19	275	4.4	4.0	4.4
Coffee20	200	1.0	0.0	1.1
Coffee21	275	0.7	0.0	0.8
Coffee22	275	0.7	0.0	1.2
Coffee23	200	0.5	0.0	0.5
Coffee24	270	0.4	0.0	0.8
Coffee25	100	0.0	0.0	0.0

Table 5: Measured values of 25 samples by three different type of saccharimeter

	PAL Coffee	PAL-J	PAL-BX/RI
Coffee1	14.54	15.28	14.60
Coffee2	15.17	15.84	15.12
Coffee3	13.01	12.58	12.50
Coffee4	12.64	12.44	12.58
Coffee5	11.76	12.44	11.90
Coffee6	12.79	12.58	12.40
Coffee7	12.66	13.26	12.70
Coffee8	10.15	10.00	9.90
Coffee9	10.74	10.98	10.70
Coffee10	9.84	10.54	10.00
Coffee11	10.61	10.68	10.52
Coffee12	9.17	9.92	9.32
Coffee13	9.16	9.80	9.20
Coffee14	9.95	10.28	9.76
Coffee15	9.92	10.62	10.06
Coffee16	4.43	5.20	4.52
Coffee17	5.10	5.96	3.70
Coffee18	5.01	4.90	4.96
Coffee19	5.02	5.10	4.88
Coffee20	0.86	1.70	1.24
Coffee21	0.95	0.90	0.80
Coffee22	0.90	0.90	1.20
Coffee23	0.95	1.80	0.98
Coffee24	1.64	1.20	1.30
Coffee25	0.00	0.00	0.00

A. in case of PAL-Coffee saccharimeter

The most important point for making a calibration curve is what to be set as the X-axis. First, we set the sugar content labeled on coffee product as X-axis. And the expected values and the measurement values obtained by using PAL-Coffee saccharometer were compared.

The red line in [Figure 1] showed the linear relationship obtained by straight equation(Y=BX+A) of measured values in the experiment. Dotted line was a hypothetical straight line appearing when assuming 1:1 relationship of expected and measured values. And <Table 6> showed the relationship (R), slope (B), and Y-intercept (A) obtained in linear relationship of measured values.

When we set the sugar content as the X-axis as shown in [Figure 1], the measurement values were higher than expected values. Especially, in the range of higher sugar content (>6g/100mL), it was also far from the expected values. The Y-intercept between measured values in [Figure 1] was 0.52836 which did not pass zero point, and the slope was as high as 1.27082. Therefore, it was found that setting sugar content as the X-axis did not accurately reflect the measured value.

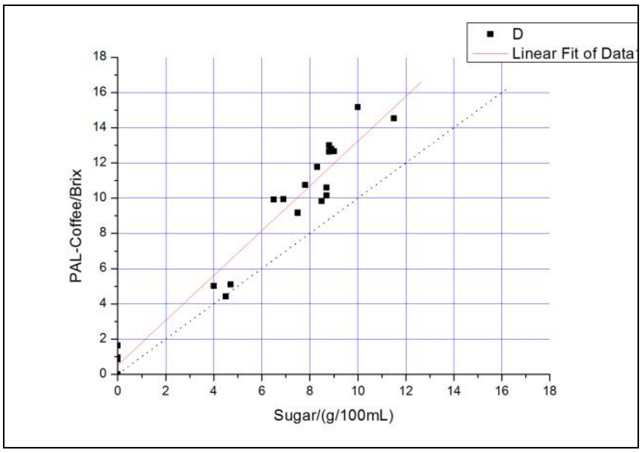

Figure 1: Correlation graph between measured values obtained by using PAL-Coffee saccharimeter and expected values converted by total sugars content.

Table 6: Linearity of measured values in figure 1

	Value	Error	
A	0.52836	0.38917	
B	1.27082	0.05671	
R	SD	N	P
0.97786	1.04724	25	<0.0001

Next, the X-axis was set as the expected value obtained by converting the carbohydrate content labeled on product. We examined the correlation with the measured value obtained by using the saccharimeter [Figure 2]. When the converted value of carbohydrate was set as the X-axis, the slope decreased from 1.270 to 1.252 and the Y-intercept was 0.0713 which was closer to the zero point.

In case of low concentration (<1g/100mL), the expected and measured value maintained 1:1 linear relationship. But with higher total of carbohydrate (>1g/100mL), the expected and measured values receded from 1:1 relation. The result also showed that the setting total carbohydrate content (including sugars) as the X-axis did not accurately reflect the measured values.

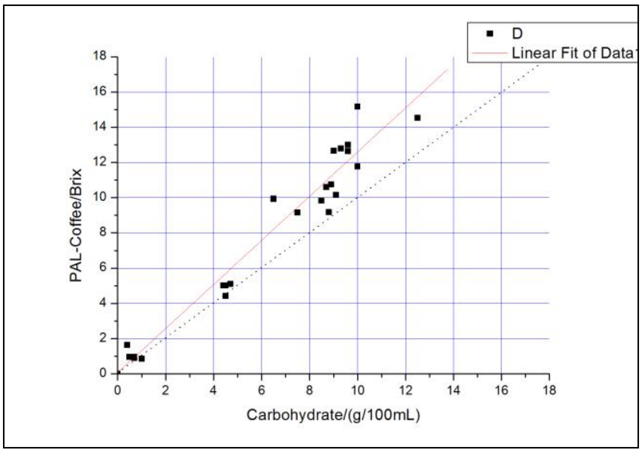

Figure 2: Correlation graph between measured value obtained by using PAL-Coffee saccharimeter and expected values converted by total carbohydrates content.

Table 7: Linearity of measured values in figure 2

	Value	Error	
A	0.0713	0.44425	
B	1.252	0.06112	
R	SD	N	P
0.97367	1.14086	25	<0.0001

Next, the expected values of total dissolved solids content which was converged values of total carbohydrate, protein, fat and other solid was set as the X-axis. As shown in [Figure 3], it showed a good conformity between expected and measured values not only at low concentrations but also at high concentrations. We obtained that the Y-intercept was 0.15396, and the slope was 1.02724. And the R was 0.99116.

In conclusion, PAL-Coffee saccharimeter was good to use for determining the sugar content in range of lower concentration (0~6g/100mL) and medium concentration (6~12g/100mL). However, it doesn't recommend for detection the sugar content when their concentration is higher than 12g/100mL.

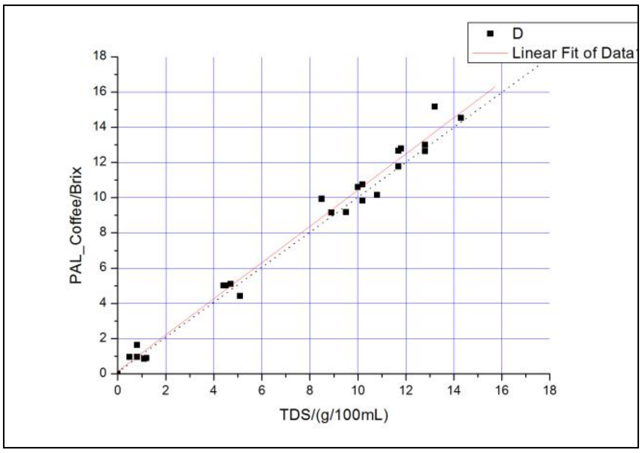

Figure 3: Correlation graph between measured value obtained by using PAL-Coffee saccharimeter and expected values converted by total dissolved solids content.

Table 8: Linearity of measured values in figure 3

	Value	Error	
A	0.15396	0.25323	
B	1.02724	0.02867	
R	SD	N	P
0.99116	0.66398	25	<0.0001

B. in case of PAL-J saccharimeter

[Figure 4] described the correlation between expected values of converted sugar content labeled on bottled coffee or canned coffee and measured values obtained by using PAL-J saccharimeter. The red line showed a linear relationship obtained by straight equipment (Y=BX+A) between measured values. The dotted line showed the hypothetical line assuming the expected and measured value is in 1:1 correlation. If red line was closer to the dotted line, it could be said that the higher the conformity between the expected and measured value were existed.

When we set the X-axis as sugar content as shown in [Figure 4], the conformity between expected and measured values grew apart not only in lower concentration of sugar content, but in high concentration. The Y-intercept was 0.76518 which did not pass the zero point, and the slope was 1.28472. The result verified that setting the X-axis as the sugar content was inappropriate.

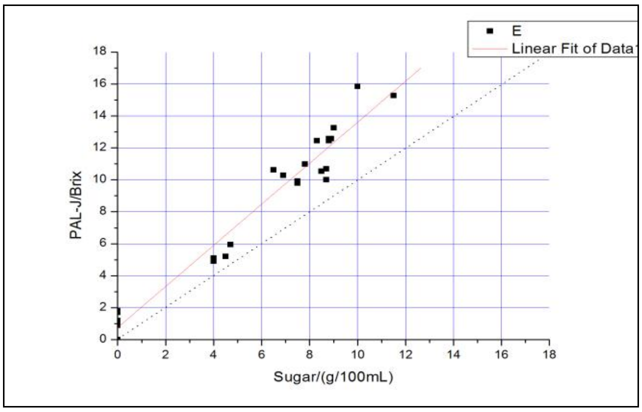

Figure 4: Correlation graph between measured value by using PAL-J saccharimeter and expected values converted by total sugars content.

Table 9: Linearity of measured values in figure 4

	Value	Error	
A	0.76518	0.38267	
B	1.28472	0.05576	
R	SD	N	P
0.97901	1.02976	25	<0.0001

Next, we set the X-axis on based on the values of total carbohydrate labeled on product to see the correlation with the measured values. As shown in [Figure 5], the slope (1.26504) decreased a little and the Y-intercept (0.38722) was closer to zero point than the case of sugar content (Figure 4). However, with high concentration (>6g/100mL) of total carbohydrate, the 1:1 conformity of measured and expected values was low. This result verified that setting the X-axis as the expected value based on the total carbohydrate did not accurately reflect the measured value.

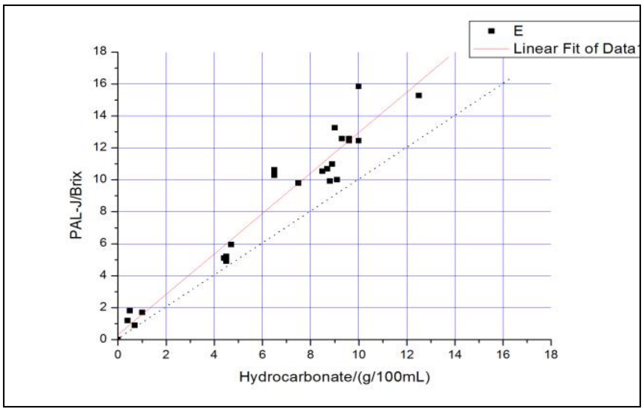

Figure 5: Correlation graph between measured value obtained by using PAL-J saccharimeter and expected values converted by total carbohydrates content.

Table 10: Linearity of measured values in figure 5

	Value	Error	
A	0.38722	0.44311	
B	1.26504	0.06097	
R	SD	N	P
0.97431	1.13793	25	<0.0001

Next, based on the expected sugar content converted by the total of carbohydrate, protein, fat and other solid as the X-axis, the correlation with measured values and expected values was examined. As shown in [Figure 6], unlike [Figure 4] and [Figure 5], it showed almost corresponding between measured values and expected values. This was to say, even in high concentration of sugar content, the measured value and expected value did not get apart from 1:1 linear relation (Y-intercept was 0.42554, the slope was 1.0331). This result showed that sugar content measured by PAL-J saccharimeter was the concentration of total solid dissolved in drinks. The relationship (R) of measured value was high with 0.9874.

However, the linearity line did not pass zero point in lower concentration verified that PAL-J was inappropriate in measuring sugar content of very low concentration coffee than PAL-Coffee saccharimeter. So, the further investigation with more samples in the range of low concentration is needed to draw the exact result.

In conclusion, this apparatus (PAL-J) was good to use for determining the sugar content in range of lower concentration (1~6g/100mL) and medium concentration (6~12g/100mL). However, it did not recommend for detection the sugar concentration when their concentration is higher than over 12g/100mL.

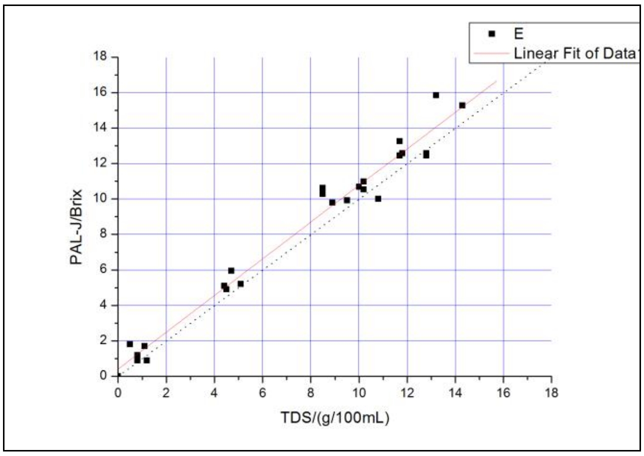

Figure 6: Correlation graph between measured value obtained by using PAL-J saccharimeter and expected values converted by total dissolved solids content.

Table 11: Linearity of measured value in figure 6

	Value	Error	
A	0.42554	0.30502	
B	1.0331	0.03454	
R	SD	N	P
0.9874	0.79977	25	<0.0001

C. PAL-BX/RI

Figure 7 showed the measured values obtained by using PAL-BX/RI saccharimeter and expected values obtained by converting the sugar content labeled on bottled coffee or canned coffee.

As shown in [Figure 7], when setting the X-axis as the values of sugar content, the 1:1 conformity between expected values and measured values got apart with higher concentration of sugar content like as PAL-Coffee and PAL-J saccharimeter. At this result, Y-intercept is 0.48176 which did not pass the zero point, and the slope was as high as 1.26415. This result showed that setting the sugar content as the X-axis did not accurately reflect the measured value.

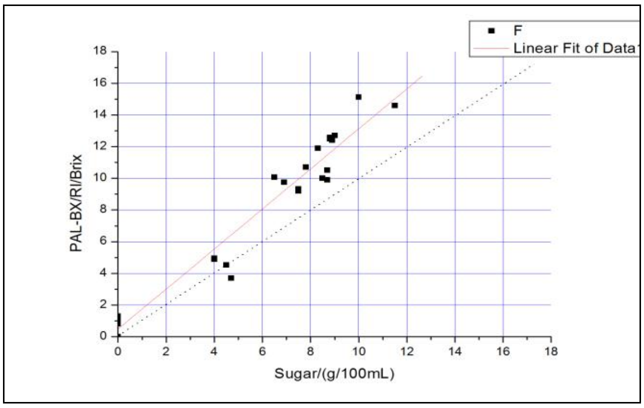

Figure 7: Correlation graph between measured value obtained by using PAL-BX/RI saccharimeter and expected values converted by total sugars content.

Table 12: Linearity of measured values in figure 7

	Value	Error	
A	0.48176	0.41999	
B	1.26415	0.0612	
R	SD	N	P
0.97409	1.13017	25	<0.0001

Next, we set the X-axis as the expected values of converted total of carbohydrate labeled on the bottled coffee or canned coffee, and then the correlation between measured values was examined. As shown in [Figure 8], the slope decreased from 1.26415 to 1.24851 and the Y-intercept was 0.00789 which was very close to the zero-point compared to previous case of setting the x-axis as sugar content. However, in this case, drinks with higher concentration (>8g/100mL) of total carbohydrate tend to have less conformity between expected values and measured values. This result verified that setting total carbohydrate as X-axis did not accurately reflect the measured values.

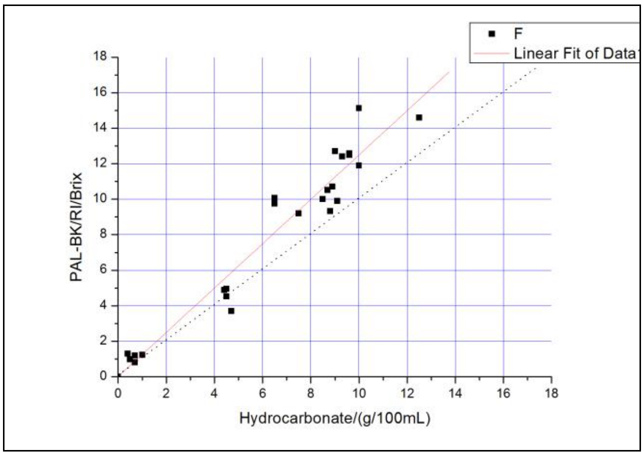

Figure 8: Correlation graph between measured value obtained by using PAL-BX/RI saccharimeter and expected values converted by total carbohydrates content.

Table 13: Linearity of measured values in figure 8

	Value	Error	
A	0.00789	0.45471	
B	1.24851	0.06256	
R	SD	N	P
0.97232	1.16773	25	<0.0001

Next, the X-axis was set as the total contents of carbohydrate, protein, fat and other solid. As shown in [Figure 9], unlike two previous cases, it showed almost corresponding value (B=1.02251, A=0.21229). Also, in high concentration of sugar contents, the expected values and measured value showed a good conformity in 1:1 relation. This result showed that the sugar content measured by PAL-BX/RI saccharimeter indicated the total solid concentration dissolved in drink. Also, the relationship (R) between the measured values increased to 0.99068. This result indicates that PAL-BX/RI is appropriated for measuring the sugar content in low concentration (>1g/100mL).

In conclusion, this apparatus is good to use for determining the sugar content in range of lower concentration (0~6g) and medium concentration (6~12g) of sugar concentration.

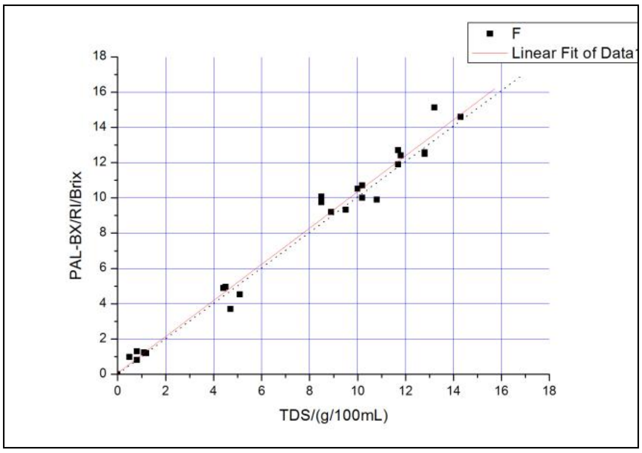

Figure 9: Correlation graph between measured value obtained by using PAL-BX/RI saccharimeter and expected values converted by total dissolved solids content.

Table 14: Linearity of measured values in figure 9

	Value	Error	
A	0.21229	0.25896	
B	1.02251	0.02932	
R	SD	N	P
0.99068	0.67901	25	<0.0001

Calculation of sugar content of unknown samples

From these results, we could be made the calibration curve for each measurement apparatuses. As for the unknown concentration of coffee bought in the market and coffee shop, the calibration curve obtained by this study was utilized to obtain the value of sugar content.

Firstly, we detected the sugar content (I) in coffee sample 1 (175ml) by using three saccharimeters with the same experiment method. The concentration of sugar (II) in coffee sample 1 was attained by adapting the calibration curve (Y=BX+A) of each measurement equipment based on the result. And obtained value (III) was converted into the standard amount (100mL) and identified it lastly. The result obtained by three measurement equipment for unknown concentration of samples was as <Table 15>.

Table 15: Sugar content for unknown concentration of samples (value of I) means an experimental value, (value of II) means a recalculated value by using the calibration curve, (value of III) means the confirmed the value by recalculated the volume)

		PAL Coffee			PAL-J			PAL-BX		
Sample	mL	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Coffee1	175	9.20	8.81	5.03	10.04	9.31	5.32	9.44	9.13	5.21
Coffee2	200	9.91	9.50	4.75	10.58	9.83	4.91	10.00	9.67	4.84
Coffee3	200	9.33	8.93	4.47	10.00	9.27	4.63	9.40	9.09	4.54
Coffee4	240	10.50	10.07	4.20	11.26	10.49	4.37	10.70	10.36	4.31
Coffee5	200	10.22	9.80	4.90	10.76	10.00	5.00	10.32	9.98	4.99
Coffee6	100	11.68	11.22	11.22	12.10	11.30	11.30	11.60	11.23	11.23
Coffee7	100	11.92	11.45	11.45	12.56	11.75	11.75	11.76	11.39	11.39
Coffee8	240	8.98	8.59	3.58	9.72	9.00	3.75	9.16	8.85	3.69
Coffee9	175	10.24	9.82	4.91	10.12	9.38	4.69	10.04	9.71	4.86
Coffee10	200	5.08	4.80	2.00	5.00	4.43	1.84	5.02	4.81	2.01

CONCLUSIONS

In this study, we could be investigated the sugar content in Korean coffee drinks by using three kinds of saccharimeter.

From this result, although there were small differences in measured values of each saccharimeters, but most of the values shared the equal sugar content.

We confirmed that the measured values obtained by saccharimeters showed not only sugar content and carbohydrate but also the total dissolved solids contained in drinks. It means that the portable saccharimeter is usable to detect the content of sugar in Korean coffee drinks when the value of TDS was used to the X-axis.

And, we could be predicted the concentration of sugar(TDS) in unlabeled coffee drinks by using the calibration curves obtained from this study. However, much more detailed analysis of samples to get the exact calibration curves is needed.

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