International Journal on Advanced Science Engineering Information Technology

Vol.8 (2018) No. 6
ISSN: 2088-5334

Non-destructive Evaluation of Monosaccharides from Two Local Rice Varieties Using NIR Spectroscopy for Disease Prevention Through Dietary Mitigation

Muhammad Makky[*], Renny Eka Putry[*], Kohei Nakano[#], Santosa[*]

[*] *Dept. of Agricultural Engineering, Andalas University, Kampus UNAND Padang, 25163 West Sumatera, Indonesia*
E-mail: muhmakky@ae.unand.ac.id

[#]*The United Graduate School of Agricultural Science, Gifu University, 1-1 Yanagido, Gifu 501-1193, Gifu Prefecture, Japan*

***Abstract*— The risk of diabetes mellitus (DM) and obesity in modern society is increasing. Uncontrolled diet and high carbohydrate consumption lead to the increase of new cases. Determined the exact amount of daily carbohydrate intake and dietary mitigation is among other solution that requires further study. In this research, two local rice varieties that commonly consumed in Padang, Indonesia, namely *Bakwan* and *Sokan Pulau* were evaluated both optically and chemically. The study used NIR spectroscopy analysis and ultra-high-pressure liquid chromatograms (UHPLC) assay to elaborate chemical compounds in the samples. The evaluation was performed to determine differences between glucose and fructose concentrations in both varieties measured at various rice qualities. The results of spectral measurements were then correlated with UHPLC data using two statistical methods, the principal component analysis (PCA) and partial least square (PLS). Models developed by the PCA and PLS were calibrated and subsequently validated. Results showed the model produced a high correlation rate for both glucose and fructose content in two rice varieties. Also, the study found that glucose content of *Bakwan* is higher than *Sokan Pulau* as well as fructose content, except for the lowest quality "Sokan Island" rice (Assorted). The results open the opportunity for policymakers as references and to create a healthier consumption pattern policy for low-income society in Padang.**

***Keywords*— NIR Spectroscopy; UHPLC; non-destructive evaluation; glucose; fructose; rice.**

I. INTRODUCTION

Rice is used as staple food by most Indonesian. There are many varieties of rice which are divided into categories based on the appearance and seed size. In West Sumatra, two cultivars of rice are widely consumed, namely *Sokan Pulau* and *Bakwan* which is medium and long grain respectively [1]. These rice cultivars are considered starchy and provides a source of carbohydrates, that constitute 18% of its mass [2].

Carbohydrate is a macromolecule and comes in two forms, Simple and Complex [3]. The simple Carbohydrates among other is the Monosaccharides, a single unit sugars (i.e., glucose and fructose), and cannot be broken down to smaller groups [3]. Immediately after consumed, these sugars quickly get into the bloodstream, increasing blood sugar and providing immediate energy [4].

Monosaccharides are present in most foods and are particularly high in Rice [5]. When consumed excessively at once, Monosaccharides can cause a significant increase in blood sugar, followed by an abrupt drop [4]. This type of fluctuation in blood sugar, if it occurs frequently, can lead to blood sugar dysregulation conditions such as hypoglycaemia and diabetes mellitus (DM) [6].

Poor diet management and high intake of carbohydrate are among the leading causes of obesity and DM in Indonesia [1]. Similar to other developing countries, most society in Indonesia consists of poor and low-income families [1]. Most of these low-income families' patterns of consumption depend on their income, which barely enough to cover their basic needs. Consequently, they always try to fulfil the needs in the least expensive way. Prices are typically higher in urban than in rural areas, and even in rural areas, the poor may pay different prices than everyone else [1]. Among others, cheap food is the best option to fulfil their calories needs, and constitute about two-thirds of their total spending [7]. In addition, with a decline in economic growth, the trend seems to be to spend even less money on food [8]. In Padang, the price of rice is determined according to its variety and quality, in particular, grain size. The *Sokan Pulau* is more expensive than *Bakwan* [1]. Each variety is subdivided among other by the percentage of broken grains, acknowledged as a standard quality parameter in the market [7]. Hence, the price is further differentiated into three rice quality categories, Premium, Medium and Assorted, each has broken grains percentage of less than 5%, less than 20% and more than 30% respectively [1]. Correspondingly, the price for these rice cultivars significantly differs, and Assorted being sold at a discounted price on the market, is the cheapest rice and mostly preferred by the poor.

Buying cheap food, promote low-income society to be more likely to have an overweight problem than those of greater means [9]-[11]. According to a study [12], as income falls, the rate of obesity rises. In the last decade, obesity has become a public health crisis. In Indonesia, the last two consecutive year show increased of obesity case by ten folds [9]-[11]. In the West Sumatera capital of Padang, the obesity census in 2014 showed more than 21% of the total population is affected by this case [9]. This condition is commonly accompanied by an increase in DM patients, up to 10 percent [10]-[11] in the following years. Among other causes, obesity is believed to be occurred by the high rate of rice consumption per capita in Padang. The city consumed 121.6 kg of rice per capita annually [1]. This value is much higher than the average national consumption of 98 kg per capita annually [7].

Overconsumption of rice can lead to excess calorie and carbohydrate intake, and caused fat accumulation, increase blood sugars and subsequently insulin levels [13]. In addition, high-carbohydrates diet, followed by the absence of activities, will cause energy imbalances in a person [14]. In a prolonged period of time, this condition leads to an accumulation of body fat. Hence obesity occurs. Obesity is an increasingly common problem [15] and recognized as a form of the disease by the WHO [16]. It is a major risk factor for the development of type 2 diabetes because it causes insulin resistance and is associated with physical inactivity [16].

To reduce the health risk related to over-consumption of carbohydrate, in particular, monosaccharides compound such as glucose and fructose, it is important to identify correctly how much a person consumed these sugars in their diet. In 2009, The American Heart Association (AHA) [17] recommended limiting sugar intake to no more than half of daily discretionary calorie allowance. The recommended maximum doses are 6 grams of glucose and 6 grams of fructose per day for women and 150% of those amounts per day for men [16]-[17]. While controlling the consumption of food-source might be one of the ways to mitigate the obesity [18], identifying the amount of carbohydrates intake, in particular, the monosaccharides [19], may offer a better solution.

Previous studies proposed determination of total sugar content in rice samples using a phenol-sulfuric acid method [20], or by another means chemical assay [21]-[24]. Although these methods offer acceptable accuracy, the processes are arduous and required huge resources with lack of practicability upon implementation.

On the other hand, rapid evaluation methods by means of spectroscopy had been successfully developed for evaluation of chemical properties of fruits and vegetables [25]-[35], as well as grains [36]. Recent developments in machine vision technologies have enabled opportunities for rapid and robust analysis to provide useful and advanced capabilities in a number of important sectors. Determination of monosaccharides in rice, in particular glucose and fructose [37], by means of spectroscopy analysis already became the main tools used to analyse carbohydrates in foods [38]. Subsequently, determination of the monosaccharide compound in samples can be performed using Ultra High-Performance Liquid Chromatography (UHPLC) [38]. The results from both measurements then can be correlated using statistical methods, such as the Principal Component Analysis (PCA) [39], and Partial Least Square (PLS) [40]-[42].

The study aimed to develop models for accurate determination of the actual content of monosaccharides (e.g., glucose and fructose) in two local rice varieties. The rice cultivars grow endemically in West Sumatra, in particular in the vicinity of Padang city. The study used non-destructive evaluation using spectroscopy analysis and validated the results through chemical measurements using UHPLC. The models for the determination of the glucose and fructose content was developed by correlating the relationship between spectroscopy data and UHPLC measurements using two statistical methods, the PCA and the PLS. The study outcomes will promote a new approach of monosaccharides assay for other local rice varieties in Indonesia. Subsequently, the results can be implemented as guidelines for the consumers and increased the capability of measurement in correlation to the awareness of dietary mitigation.

II. Materials and Methods

Two local rice varieties obtained from a local market in Padang, West Sumatra, Indonesia. The quality for each variety is segmented into three groups, according to their physical properties (e.g., grain size and percentage of the broken kernel). The groups are categorized as Premium, Medium and Assorted. The Premium rice graded for having percentage broken grains of less than 5%, following with other superior physical properties, such as chalkiness, grain size, shape, grain colour, and strong aroma. The Medium rice has broken grains between 5% and 20%, while its physical properties were inferior to the "Super." The Assorted rice consider as low-quality and contain a percentage of broken grains of more than 30%. In addition, its physical properties are regarded as substandard, while its low-priced valued mostly by low-income family. In total samples are grouped into six categories, according to variety and quality indices.

The moisture content of the samples was determined using a grain moisture meter (G-7, Delmhorst. USA). The device has moisture content range from 9 to 30%. It has built-in correction factors for various grains such as barley, coffee, corn, flax, hay, oats, rapeseed, rough rice, sorghum, soybeans, wheat, and rye. The grain meter has built-in temperature correction over the range of 0 to 37 ^{o}C.

The Physical Properties of the rice determined by measuring three linear dimensions of the kernel, namely length (L), width (W) and thickness (T), carefully assessed using micrometre gauge with an accuracy of 0.01 mm. The geometric mean diameter (GMD) and sphericity ratio were computed according to Mohsenin [43]. Sphericity was useful to determine the quality of grain. Sphericity is the ratio between Geometric Mean Diameter (GMD) with Length seed. Bulk density affects the process of transportation of materials, and the value of bulk density is different for every grain. Bulk density values can be determined by determining the volume of 1000 grains and subsequently its mass measured using analytical balance (Mettler Toledo, Switzerland).

For monosaccharides evaluation, 20 grams of rice samples from each category were crushed into fine rice flour using a grinder machine. The powder then sieved using 325 mesh auto sieve shakers. The size of the particles passing the sieve is considered uniform with the size of 44 micrometres. 1 g of the rice powder then put into a test tube and dissolved with 10 ml of ethanol mixture (70% ethanol and 30% Milli-Q water). The solution subsequently homogenized using vortex for 1 min with the vibrating speed of 8/10. Afterward, it was placed into Ultrasonic Bath (filled with distilled water) for 15 minutes to maximize the monosaccharide extraction. The solution then centrifuged at 4000 rpm for 10 min, and the supernatant was taken by micropipette and decanted before injected through a UHPLC grade filter (0.45µm). The sample then stored in 1.5 ml vial and put into UHPLC autosampler.

The UHPLC system used in this study is the ThermoFisher Scientific Diode Ultimate 3000 RS UHPLC. The samples were injected into the UHPLC device by the autosampler, and the solvent used was the mixture of Acetonitrile (60%) and Milli-Q water (40%). The instrument flow rate was set at 0.8 ml.min-1 flowing through column (Asahipack NH2P-50 4E No. N1630067) of 4.6 mm ID x 250 ml with the temperature maintained at 35 ^{o}C (isothermal), and pressure kept at 100bar. The standard used for Glucose and Fructose were obtained from Nacalai Tesque (Kyoto, Japan). The detector used was Fluorescence and charged aerosol detector (CAD). The test results were presented in graphs and tables.

For spectral measurements, the samples from each category were placed inside the crystal cuvette. The samples then put into its placement, with the size of 2.5x2.5x3.5 cm, filled with 15 grams of rice samples. The cuvette was then placed next to the NIRS sensor and illuminated from the opposite direction of the sensor. The light source is the SL5 deuterium-halogen system. All measurements replicated 10 times.

The samples the measured using FT-IR IPTEK T-1516 spectrophotometry. The diffused reflectance data obtained from the measurements were transformed into a spreadsheet. The wavelengths considered for the measurements were between 1000 nm and 2500 nm. Spectral data in the spreadsheet then processed using Unscrambler® X version 10-1. Statistical analyses performed using PCA to understand the grouping of samples as well as the principal components for each rice category. The diffused reflectance data was put as variable Y, while the wavelengths were assigned as variable X in the Unscrambler®.

For developing the model, two third of data were used for calibrating the model while the rest of the data used as test cases for model validation. The models were developed to determine glucose and fructose levels in the samples. The models were developed using the PLS method, by correlation the relationships between spectral data of the samples and it is nutrient values as determined using the UHPLC. The PLS analyses used the NIR diffused reflectance data for the input variable, and the concentration of glucose and fructose of the sample (from UHPLC measurements) considered as factors. Models accuracy determined by correlation (r), the coefficient of correlation (R2), root mean square error of calibration (RMSEC), root mean square error of prediction (RMSEP) and Bias.

III. Results and Discussion

From the initial measurements, the physical properties of rice from two varieties were presented in Table. 1. The results indicated that, in general, the grains moisture contents are similar for both varieties, regardless of their quality grades. On the other hand, according to the physical properties, quality-grade Premium have the superior dimensional size in all three linear dimensions of the kernel (X-Y-Z), while lowest one is the Assorted grade. From this result, the consumer may observe that Premium grade rice has significantly larger kernel size compare to Medium while broken kernel will most probably observe and found in Assorted grade, regardless of its variety. While low-income consumers may only concern about the price of the product they purchased, middle-class consumers will probably concern both price and quality and choose the product according to their value. Moreover, for the rich, the option is clear and mostly obtained the Premium grade quality, since the price of the product is less concerned by this social class.

TABLE I
PHYSICAL PROPERTIES AND MOISTURE CONTENT OF TWO LOCAL RICE VARIETIES ACCORDING TO QUALITY GRADE

Variety	Grade	Measure Dimension (Average)*		
		Length (mm)	Wide (mm)	Thickness (mm)
Bakwan	Premium	6.964 b	2.225 ab	1.384 b
(m.c. 9.733%)	Medium	6.617 b	2.195 ab	1.352 ab
	Assorted	6.270 b	2.165 ab	1.320 ab
Sokan Pulau	Premium	6.193 ab	2.964 b	1.351 ab
(m.c. 9.766%)	Medium	5.838 ab	2.193 ab	1.318 ab
	Assorted	5.483 a	1.422 a	1.285 a

*Means followed by the same letter within a column are non-significant at P = 0.05 by Duncan’s multiple range tests.

Although size does matter, the appearance of rice is not all about size. Certain consumer prefers longer grains while another favour more spherical rice. The option is subjective and cannot be quantified, since the demand may be shifted between seasons or occasions. In this study, the samples’ GMD were calculated at 2.702 for *Bakwan* and 2.563 for *Sokan Pulau*, meaning that, *Bakwan* appears to have longer grains while *Sokan Pulau* is phisically more spherical in nature. In the local market, both varieties have their own demand, and it cannot be concluded which one is more preferable to the consumer. Although Sphericity was useful to determine the quality of grain, consumers demand may be different in places. Since consumers in Padang have similar demand for both *Bakwan* and *Sokan Pulau* rice, the sphericity may not include in their option during purchasing the products. Nevertheless, in this study, the sphericity of samples was determined, and the results provided that the sphericity of *Bakwan* is 0.409 and *Sokan Pulau* is 0.44. Thus, the physical appearance both cultivars significantly differ.

Bulk density affects the process of material flows and transportation. The value of bulk density is different for every grain. In this study, the sample bulk density determined by measuring the volume of 1000 grains and subsequently measured its mass using analytical balance. The results were 0.842 g.cm-3 and 0.807 g.cm-3 for *Bakwan* and *Sokan Pulau* respectively. Since no significant difference was observed between the two samples, it is safely presumed that variety has a weak relationship with rice bulk density, as well as its quality grades.

The monosaccharides of the samples were measured using chemical analysis and assay using UHPLC. Two distinctive components were considered in this study, Glucose, and Fructose. Both are single unit sugars and cannot be broken down to smaller units. When consumed, these sugars rapidly absorbed into the bloodstream, increasing blood sugar and providing immediate energy. However, these compounds produced health risk when consumed excessively at once. Each can cause a significant increase in blood sugar, followed by an abrupt drop, causing fluctuation and when combined with frequently occurrences, can lead to dysregulation conditions such as hypoglycaemia and DM.

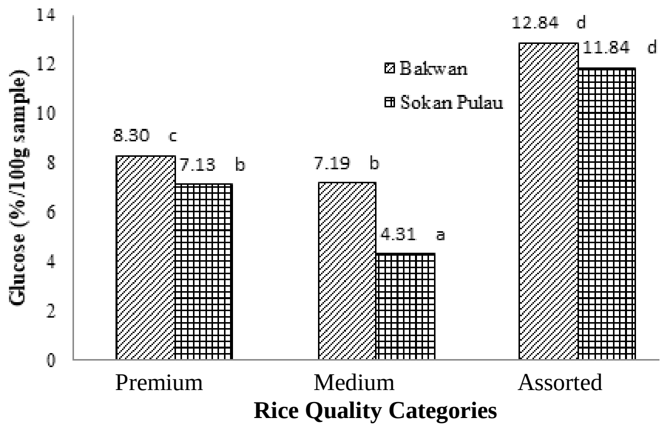

Fig. 1 Samples' Glucose Content as Measured by UHPLC. Variety and quality-grade determined the amount of glucose in samples.

The results (Fig. 1) suggest that *Bakwan* has higher glucose content compare to *Sokan Pulau* rice. The glucose content in *Bakwan* and *Sokan Pulau* significantly differs according to Duncan's new multiple range test (MRT) (p, 0.05), and similarly differ for each quality grade (Premium, Medium and Assorted). Moreover, the grain size also influences the amount of glucose. Assorted, being the lowest grade, surprisingly content more glucose, in particular from Bakwan cultivar, while Medium has the lowest concentration per sample mass, especially from Sokan Pulau cultivar. Being preferred by most low-income household, the results suggested that, these consumers may have higher sugar intake, and since these sugars rapidly absorbed into the bloodstream upon consumed, it will immediately provide energy. Since low-income family consumed high carbohydrate in their diet, the condition translates as higher risk for the poor to diseases such as obesity and DM. On the other hand, a family with better welfare did not automatically have the lowest risk of obesity and DM. From this study, the glucose content in rice with Premium grade, were higher compare to the Medium grade. However, since rich people mostly consumed protein and fat in their diet, the number of carbohydrate intake is smaller and as such, reduced their daily consumption of Glucose. In general, *Bakwan* rice has higher glucose content compare to *Sokan Pulau* thus expose higher risk potential to the consumer who prefers this product. The results can be utilized by the policymaker for providing suggestion to the society on how the should choose and consumed their rice. In detail, the glucose concentration in *Bakwan* rice is 8.3, 7.19, and 12.84% for Premium, Medium and Assorted quality-grade respectively. For the *Sokan Pulau* the glucose amount in three quality grades are 7.13, 4.32, and 11.84% for Premium, Medium and Assorted respectively.

The average carbohydrates in rice are between 77 and 79 g [44] per 100gr of the sample. A small portion of the carbohydrates are in the form of simple sugar [6], weighed between 0.1 and 0.12 g [14]. The value dictated by varieties, moisture content and milling process [19]. Sugar in rice is generally in the form of the monosaccharide and dominated by glucose and fructose. According to the FAO [44], the average consumption of rice for a single meal is 158 g/capita. In comparison, the average consumption of rice in West Sumatra is 121.6 kg/year/capita or equivalent to 166.58 g per meal per capita. Therefore, quantitatively, consumers in Padang have 5.5% higher rice in their diet, compare to the average daily intake. With this high-level of consumption, when Assorted *Bakwan* rice is in their daily menu, the total glucose consumed by one person is 15613.9 g/year. The average body-weight of people in Padang is 60 kg [9]-[11], and according to FAO standard [44], the maximum amount of glucose and fructose intake is 36 and 24 grams for a male and female person, or equal to 13140 and 8760 gr. year-1. capita-1 for men and women. Consequently, in Padang, consumption of glucose is almost two times higher than the normal conditions. When accompanied by low activity and metabolism, then this excessive glucose intake will accumulate in the body into layers of fat which are difficult to digest. In long-term, this condition will lead to obesity which ultimately increases the risk of DM disease in the community.

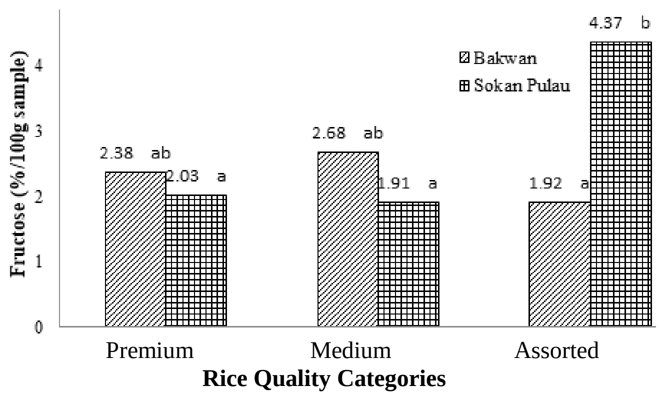

Fig. 2 Samples' Fructose Content as Measured by UHPLC. Variety and quality-grade determined the amount of fructose in samples.

Dietary Mitigation for reducing total sugar intake can be promoted by consuming less "sweet" rice such as the Basmati, or even fewer sweet carbohydrates such as brown basmati or low glycaemic rice. Sugar in rice is in the form of monosaccharides, in particular glucose and fructose. Based on Harvard glycaemic index [19], consuming white basmati rice may reduce the sugar intake as low as 10506.5 g/year/capita. In addition, consuming brown basmati or even the low glycaemic rice will make annual sugar intake of a person to 7296.2 and 5545.12 g/year. In addition to excessive consumption, the sugar contents in local rice (*Bakwan* and Sokan Pulau") alone is higher compared to another cultivar, such as Basmati. Thus, the risk for obesity and DM in Padang is consequently higher to others city in Indonesia.

Monosaccharides are carbohydrates with the smallest molecular size consisting of components, among others are glucose and fructose. Similarly, in this study, the rice samples also contain the two main components of monosaccharides, e.g., glucose and fructose. From UHPLC measurements results (Fig. 2), the fructose concentration in most samples is similar, except in the Assorted *Sokan Pulau* grade. The results suggest that rice varieties do not directly corresponding to the difference of fructose amount, while the grain size, correlated to the quality-grade of the products, only differ when a certain number of the kernel is sufficiently damaged, especially more than 30% in the rice samples. Being preferred by most low-income household, the results suggested that, these consumers may have higher fructose intake, and together with the glucose obtained from the same products, the total sugar consumed will rapidly be absorbed into the bloodstream. Again, this condition strengthens the idea that low-income family has higher health risk condition due to their choice of cheap food. Exposing their family to unhealthy food is the consequences to their low purchasing power, due to limited income. Therefore, in Padang, the obesity and DM occurred more frequently in poor society, or low-income family (Fig.3). From the report of government health agency in Padang [9]-[11], the chance of obesity is higher in female rather than male, especially in the larger family. While fulfilling their need expend most of their time, but the rate of activity at the same time is minimal since most of these females occupy job which demands them to sit or stand in extremely long time, such as waitress, cashiers, or front-desk.

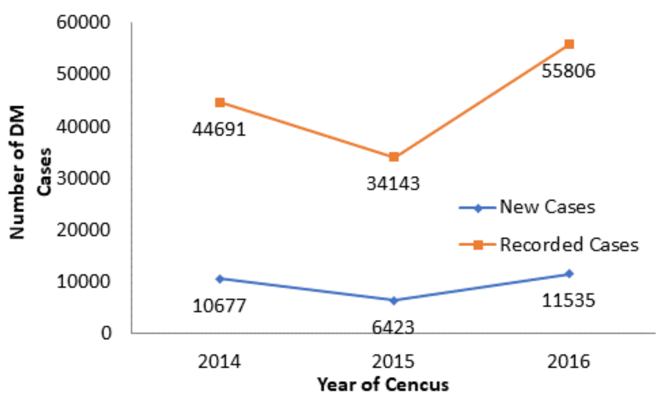

Fig. 3 The occurrences of DM cases in Padang according to the year of the census

On the other hand, a female member in the family with better welfare only have limited cases reported and most cases of DM that not accompanied by obesity. Rich family mostly consumed protein and fat in their diet, while the number of fructose intake is less, thus reducing their total daily consumption of sugar. While in general *Bakwan* and *Sokan Pulau* obtained the similar concentration of fructose (Fig. 2), quality selection by low-income family, in relation to the product price upon purchasing, increased their tendency to consume more sugar compared to other better economic strata family. The results can be used for the policymaker to advocate the low-income family to choose other variety of rice for their consumption, with similar price, here in our study is the Assorted Bakwan quality grade. Furthermore, since the fructose concentration in the late product is smaller compared to other samples in this study, the families with premium and medium purchasing power may as well reconsider their preferences upon buying the rice. Here, in our cases, cheaper is better in term of fructose concentration in *Bakwan* rice. In detail, the fructose concentration in *Bakwan* rice is 2.38, 2.68, and 1.92% for Premium, Medium and Assorted grade respectively. For the *Sokan Pulau*, the fructose amount in these grades are 2.03, 1.91, and 4.37% for Premium, Medium and Assorted respectively.

From 100 g of sample, 12 g is measured as total monosaccharides (sugar), while 9,16 g of this is the combined weight of glucose and fructose. Naturally, Fructose has a low level of the Glycaemic index, but when consumed in large quantity may double the glycaemic level in blood sugar, especially for the elderly. The glycaemic index indicates a condition in which the consumed food has an effect on the condition of blood sugar of a person after consuming food within 1 or 2 hours. Foods with the high Glycaemic index when consumed will create spikes of blood sugar, resulting in excessive insulin present in the blood. When this condition continuously occurred, it will disrupt the insulin production in a person and obstruct the body to process sugar (e.g., fructose) normally, here the chance of occurrence of DM is high.

In term oh health, fructose promotes more health-related issue than glucose, especially for those who have a high risk of DM. Consuming fructose tends to further increase a person's weight compared with glucose. Thus, it is causing more obesity compared to glucose when consumed at the same level. However, in this study, the fructose concentration in samples is lower than the glucose, approximately one-third of the later concentration.

Rice is among the food that is considered to have a high glycaemic index. The glycaemic index of rice is 70 [19] and beyond, which indicate that if consumed by a human, it will release sugar quickly and directly discharged to the bloodstream, causing the person to become hungry in short time. This fast and frequent feeding condition is called postprandial or reactive hypoglycaemia. This condition caused a person to crave something sweets after a meal. The condition usually occurs one to four hours after a person consumed rich carbohydrates food, such as rice. This rebound hunger caused by consuming high-fructose foods, which reduced blood flow and activity in brain regions that regulate appetite, satiety, and fullness. This condition did not occur when the same person consumes glucose even at the same amount. A previous study [45] indicates that fructose can trick brains into craving more food, even after consumed heavy meals. It reduced the ability of the body to use satiation hormone (e.g., leptin), resulting in the low awareness of being full.

Consuming rice in large quantity is not healthy, due to its high glycaemic index, indicating by the high concentration carbohydrates, constitute of fructose and glucose. However, when the energy expenditure of a person is high, especially when doing exercise or heavy work, then rice is more suitable to consumed. This food is faster to digest for replacing the lack of glucose in the bodies. Therefore, people who work hard may consume a slightly larger quantity of rice. On the other hand, for those who have low activities metabolism, the job does not require a person to spend high calorie, then rice should be consumed in small quantity (less than 100g/day), since it will cause the risk of obesity.

Although in general the glycaemic index of rice is high, the number depends on variety and its physical properties. Some rice has high amylose and amylopectin, while others have a significantly lower level but high in protein. In this study, the local rice variety (*Sokan Pulau* and *Bakwan*) are considered as high glycaemic index rice, especially when compared with “Basmati” rice.

In order to reduce the risk of diabetes and obesity, a person can substitute rice in their diet with other carbohydrate sources obtaining the lower glycaemic index, such as wheat or bread. In addition, obesity and DM can be prevented by consuming lots of fruits and vegetables, both neutralized the effect of blood sugar spikes in the body. Other means of dietary mitigation for reducing the risk of obesity is by consuming less food, but not to exceed 15% of the normal meal condition [46]. Otherwise, it will make a person hungry faster than normal time, and causing frequent feeding. At 15% reduced calorie intake, the body will automatically extract the fat inside the tissues, and while the process may be longer for reducing the weight than the strict diet, but it is surely the healthiest way.

For reducing the glucose and fructose intake without slashing down the daily consumption, dietary mitigation through substitution of carbohydrate source can be one of an option. Purchasing better rice quality, for instance, may reduce glucose and fructose intake 67% and 44% respectively. This can be achieved by substituting the Assorted grade *Bakwan* with Medium *Sokan Pulau* for glucose dietary mitigation. Also, substituting the Assorted grade *Sokan Pulau* with the Medium grade may promote dietary mitigation for fructose intake. In general, the better economic condition is the obvious solution to prevent low-income family consuming cheap food. Thus, the risk of obesity and DM will subsequently be alleviated.

For people with low purchasing power, the risk of diabetes is higher. The reason is low-grade rice has lower price while the glucose content is 78% higher than the average. Consumer economic factors determine the selection of rice quality and subsequently determine the amount of glucose intake which result in higher risk of diabetes.

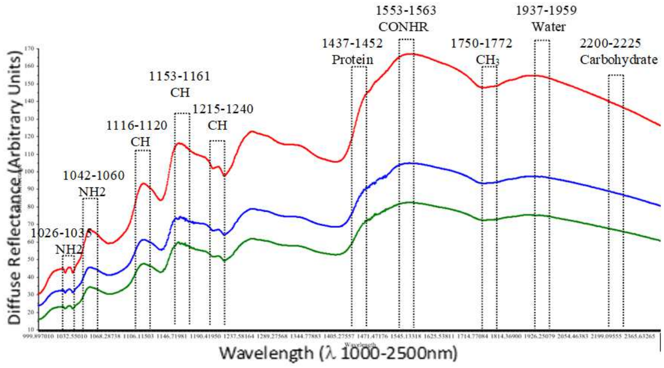

Fig. 4 Spectrum properties of *Bakwan* rice when measured using a diffused reflectance method within a 1000-2500nm wavelength. The three lines represent a quality grade of Premium (Blue), Medium (Red), and Assorted (Green).

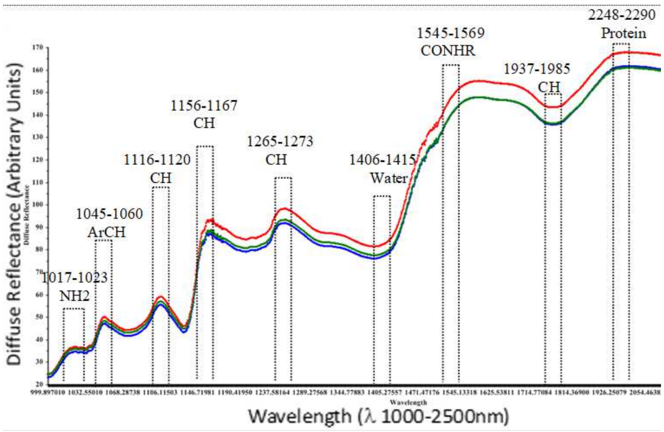

Fig. 5 Spectrum properties of *Sokan Pulau* rice when measured using a diffused reflectance method within a 1000-2500nm wavelength. The three lines represent a quality grade of Premium (Blue), Medium (Red), and Assorted (Green).

For modelling the glucose and fructose, the rice samples were scanned using NIR spectroscopy. The scan methods were diffused reflectance, with the spectrum range of 1000nm until 2500nm. The results of spectral reflectance for *Bakwan* and *Sokan Pulau* rice is presented in Fig. 4 and Fig. 5 respectively.

In recent developments, machine vision technologies have enabled opportunities for rapid automatic analysis, providing useful and advanced capabilities in a number of important sectors, in particular, the non-destructive evaluation of food products. The spectral properties of two local rice varieties (Fig. 4 and Fig. 5) showed difference reflectance values, and a number of peaks, suggesting that the chemical composition of both sample types is significantly different. While different quality grades of *Bakwan* rice have distinctive values, the case is less observed with the *Sokan Pulau* samples. Since the particle size may influence the spectral results, the results indicate that quality-grade differential of *Bakwan* rice is much greater than the *Sokan Pulau* and thus are more easily to observe by the consumer. Furthermore, certain chemical bound is not present in *Bakwan* and *Sokan Pulau*, suggesting that the chemical composition of both varieties have differences. This may have a relationship with flavour and aroma as well as taste when process and consumed, explaining why consumers have different preferences toward both varieties. While carbohydrates bounds are present in *Bakwan* upon spectral assessment, the same results are absented in *Sokan Pulau*. Based on UHPLC chemical assay, the carbohydrate compounds in *Sokan Pulau*, here glucose and fructose, are consistently lower compare of the *Bakwan*, except for fructose content in Assorted grade quality. Consistently with this result are the spectral values of both rice cultivar, which differ in results. To better understand how the spectral results can be utilized for non-destructive evaluation of rice nutrient content, a statistical procedure, namely principal component analysis (PCA) was performed.

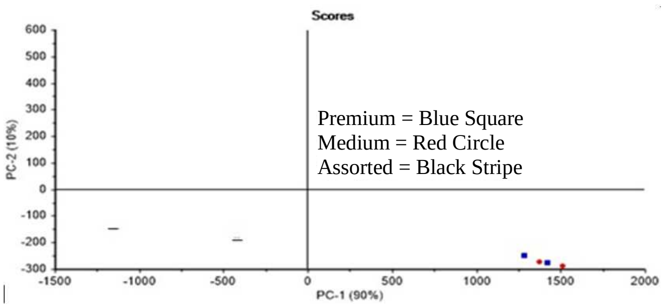

Fig. 6 PCA of *Bakwan* rice with three quality grades (“Super, Medium, and Assorted)

The PCA used orthogonal transformation to convert samples’ reflectance data that possibly have correlated variables into a set of values of linearly uncorrelated variables. The number of these uncorrelated variables (principal components or PC) is less than the number of original variables. The PCA transformed spectral data in such a way that the first PC has the largest possible variance, and each succeeding PC, in turn, has the subsequent highest variation possible. The PCA of *Bakwan* and *Sokan Pulau* is presented in Fig. 6 and 7 respectively.

The PCA results for *Bakwan* rice clearly distinguished between high and medium grade (Premium and Medium) with the lowest one (Assorted). Nonetheless, the analysis failed to classify differences between Premium and Medium. As such, it is not sufficient to directly model the quality grade for this cultivar.

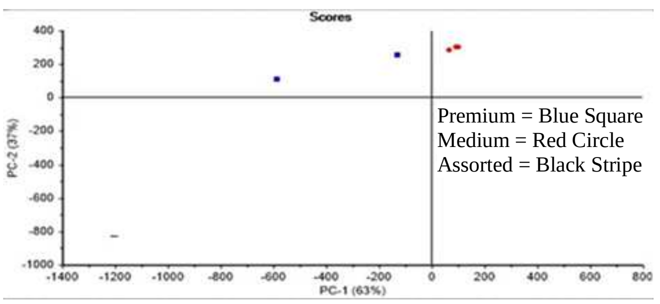

Fig. 7 PCA of *Sokan Pulau* rice with three quality grades (“Super, Medium, and Assorted)

On the other hand, the PCA results for *Sokan Pulau* rice clearly distinguished all three quality grades of the rice, namely Premium, Medium, and Assorted. Also, the analysis showed that the Medium is grouped in close proximity, while Premium and Assorted were widely dispersed. This indicated that samples of Medium grade have less variation compare the other two grades, hence the appearance will look alike to the consumers.

The PCA for two rice varieties explained correlated variables into two transformed principals’ component (PC). For *Bakwan*, the first and second PC (PC-1 and PC-2) explained 90% and 10% of all spectral variables of the samples. Whereas for "Sokan Pulau," PC-1 and PC-2 explained 63 and 37% spectral data respectively.

In order to accurately model two main components of monosaccharides (e.g., glucose and fructose) concentration in samples, the Partial Least Square (PLS) is statistical analysis was used. The PLS explained the relationships between the concentration of glucose and fructose in the sample with spectral data obtained from the measurements. The results are explanatory models, a straightforward and reasonable way of forming prediction equations. The calibration and validation model for predicting glucose content in *Bakwan* rice is presented in Fig. 8 and 9 respectively. The calibration model (Fig. 8) obtained a high correlation of 0.968 with RMSEC of 1.229 and Bias of 3.17x10-7. Although an offset of 1.417 is present, the model considered fit for predicting the glucose content, with acceptable accuracy. In addition to offsetting, data boundary and outlier can shift the model to some extent that the accuracy value decreases and there is considerable noise. The magnitude of the effect of the shift that occurs is determined by the amount of data used to build the model. With the low offset and RMSEC obtained in the model, the noise and outlier data can be considered as a minimum.

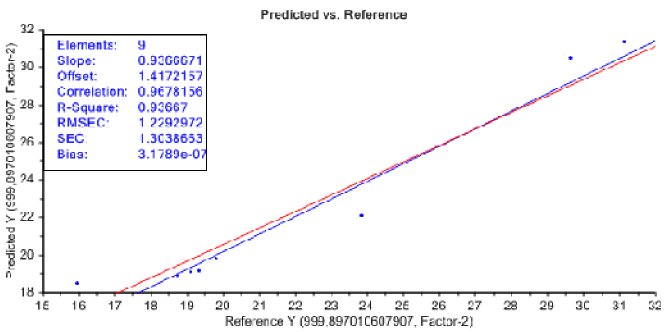

Fig. 8 Model calibration for glucose concentration prediction in *Bakwan* rice according to diffuse reflectance data and chemical assay by UHPLC.

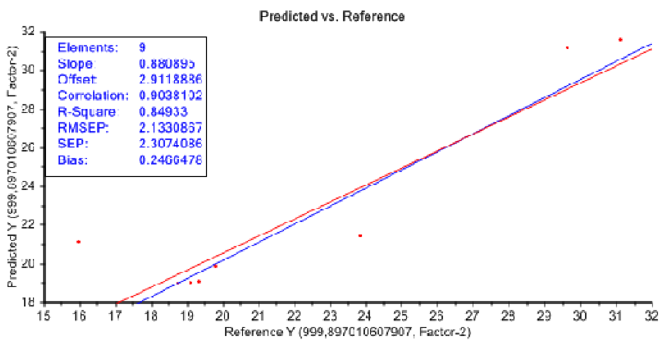

Fig. 9 Model validation for glucose concentration prediction in *Bakwan* rice according to diffuse reflectance data and chemical assay by UHPLC.

Validation model (Fig. 9) presented a similar high correlation between actual glucose content in rice samples and the prediction values produced by the model. With an offset of 2.912 and R2 of 0.849, the model miss-prediction is still within the expected boundary, explained by the RMSEP value of 2.133 and bias of 0.247.

The calibration and validation model for predicting glucose content in *Sokan Pulau* rice is presented in Fig. 10 and 11 respectively. For the calibration model (Fig. 10) obtained a high correlation of 0.990 with RMSEC of 0.529 and Bias of -0.6357. Although offset of 0.498 is present, the model considered fit for predicting the glucose content, with acceptable accuracy.

For the validation model (Fig. 11) of glucose concentration prediction in *Sokan Pulau* rice, the similar high correlation between actual glucose content in rice samples and the prediction values were shown by the model. With the offset of -1.711 and R2 of 0.870, the model miss-prediction is still within the expected boundary, explained by the RMSEP value of 1.569 and bias of -0.413.

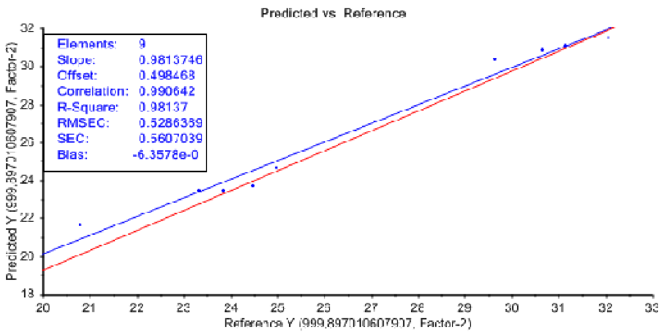

Fig. 10 Model calibration for glucose concentration prediction in *Sokan Pulau* rice according to diffuse reflectance data and chemical assay by UHPLC.

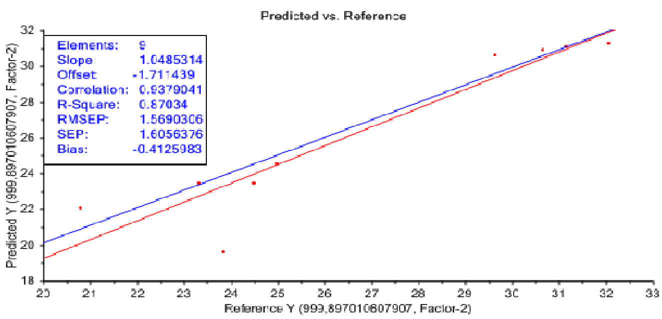

Fig. 11 Model validation for glucose concentration prediction in *Sokan Pulau* rice according to diffuse reflectance data and chemical assay by UHPLC.

Even though the concentration of glucose and fructose of the two rice varieties were different and varied according to their quality grade. The values could be grouped, according to the percentages of broken grain as well as the grain size. Eventually, all models developed in this study, have the ability to predict the concentrations of glucose in samples with an accuracy of more than 90%. In addition, the model's predictive range was sufficient for predicting the glucose concentration in rice samples non-destructively, based on diffused reflectance data when the samples were measured using spectrophotometry.

Based on the PLS analyses, determination of glucose according to the NIR diffused reflection can differentiate the concentration of glucose in the samples. Determination glucose influenced by three physical properties, namely percentage of broken rice, glucose concentration in samples, and spectral reflectance from the samples. Rice with the best quality was plotted in the group in the graph. The place is influenced by the concentration of glucose and model predictions. Higher glucose content moves the data position along with Y axis. The UHPLC data influence the model, here data were weighted according to their correlation to the factors in the model, whether significantly or not. Correlation between data and factors upon model development depend on the data variation, which in turn, greatly affect the resulting models. The validity of the model is closely related to the accuracy of the data. The contribution of the input variable can be evaluated, and ranked according to the degree of influence for every data into the models. The sensitivity of the models has strong relationships with the variation of data and similarity between variables.

In this study, the accuracy of the models to determine the quantity and concentrations of chemical components in the samples can be translated with its low residual values. The results suggested that the spectral device being used not be sensitive enough to detect minuscule glucose concentration in the sample accurately. The reason may lay with the photo-electro-optical sensor in the instruments, as well as the intensity of illumination upon recording the spectral data. Higher illumination intensity will produce more energy from the light source, and when this energy falls onto the organic compounds, the atoms and its energy bound will naturally vibrate, releasing a greater number of photons, and consequently, the sensors will be able to capture this emission and recorded as better spectral data. Other plausible caused was the noise that generated by the internal parts of the instruments, or the surrounding environment. These noises may interfere with the actual spectral reflected by the samples and thus producing a false reading in the instrument. Nonetheless, both cases can be neglected since the influence is insignificant. In addition, the sensitivity of the equipment used can be improved for future studies, while the lighting intensity can be enhanced. Therefore, in the near future, even the lesser amount of glucose can be detected by such systems, and the results will produce better models' accuracy in comparison to the present results.

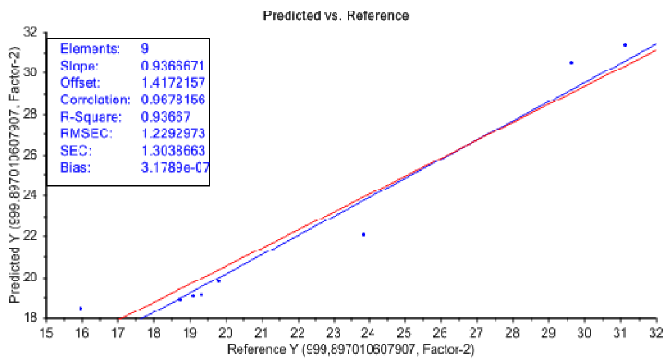

Fig. 12 Model calibration for fructose concentration prediction in *Bakwan* rice according to diffuse reflectance data and chemical assay by UHPLC.

Similar to the model for glucose prediction, the developed models, for non-destructive fructose evaluation for *Bakwan* rice produced a high correlation of 0.968. The model prediction accuracy is determined by the RMSEC of 1.229

and bias of 3.18x10-7, indicating most of the data correctly predicted by the model. Furthermore, the model offset is minimal with a value of 1.417, suggesting that outlier data is fewer than a normal distribution. Thus, the data is more gather toward the center (average) value. The graph (Fig. 12) also showed that the model predicts more accurately when the fructose concentration is lower, compared to the rice sample with a higher quantity of fructose.

Subsequently, the validation model (Fig. 13) for predicting fructose content in *Bakwan* rice, obtained a high correlation of 0.904 with RMSEP of 0.2.133 and Bias of 0.247. The offset of 2.912 is observed, implying the model influence by some outlier data although it still being considered as fit for predicting the glucose content, with acceptable accuracy.

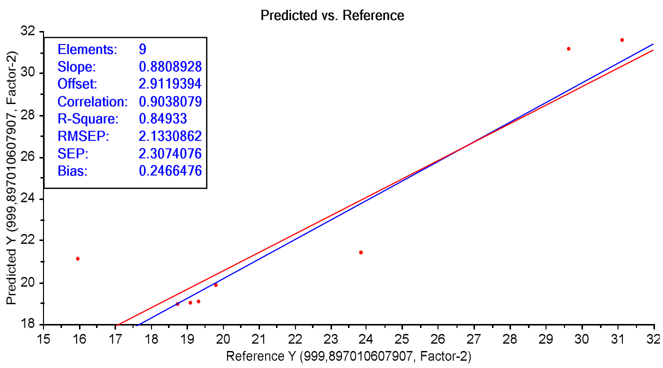

Fig. 13 Model validation for fructose concentration prediction in *Bakwan* rice according to diffuse reflectance data and chemical assay by UHPLC.

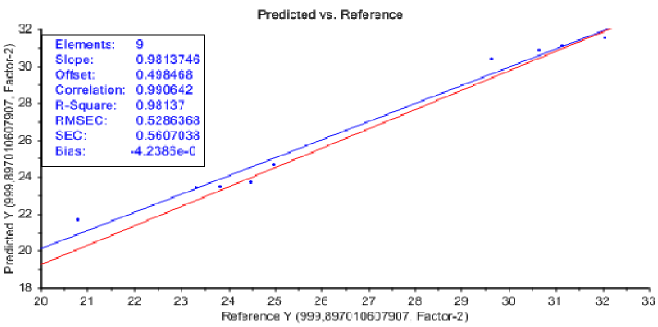

Fig. 14 Model calibration for fructose concentration prediction in *Sokan Pulau* rice according to diffuse reflectance data and chemical assay by UHPLC.

Comparably, the calibration and validation results for models, developed in this study, for predicting the fructose in *Sokan Pulau* rice obtained a similarly strong correlation with the value of 0.904 and 0.990 for calibration and validation models respectively. The calibration model (Fig. 14) generated offset of 0.498, R2 of 0.981 and RMSEC of 0.529. Also, the model bias is calculated at -0.4239 and the slope of 0.981 showed that the predicted data distribution is leaned towards the higher concentration fructose value. Furthermore, the validation model (Fig. 15) for the determination of fructose in *Sokan Pulau* rice produced a comparable high correlation value, of 0.938. The model RMSEP is 1.569, and bias is determined at -0.413. The model leans towards the fourth quadrant resulting a negative offset of -1.711 with a slope of 1.049. The results suggested that all models developed using PLS obtained acceptable accuracy, while the sample data can be considered as homogeneous.

The study has comprehensively evaluated two monosaccharides compounds in local rice varieties, namely *Bakwan* and *Sokan Pulau*. The two compounds under consideration were glucose and fructose. Both are simple sugars, and when consumed cannot be broken down to smaller units by the body. Immediately after consumed, these sugars quickly get into the bloodstream, increasing blood sugar and providing immediate energy. However, both sugars can cause a significant increase in blood sugar, followed by an abrupt drop, and if it occurs frequently, can lead to blood sugar dysregulation conditions such as hypoglycaemia and DM. In this study, the number of samples used is limited by the availability of laboratory equipment and facilities as well as the workforce. Nevertheless, the models produced showed acceptable accuracy with insignificant noise or disturbance in the results.

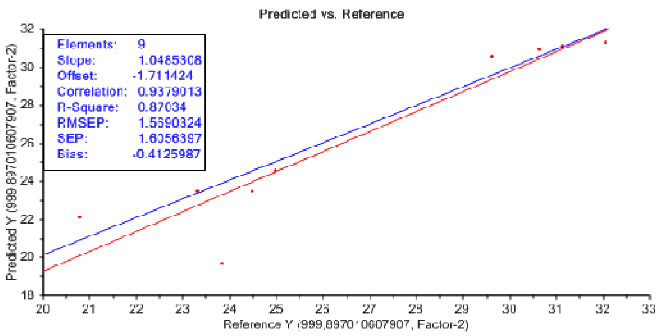

Fig. 15 Model Validation for fructose concentration prediction in *Sokan Pulau* rice according to diffuse reflectance data and chemical assay by UHPLC.

IV. Conclusions

From this study, it is understood that the monosaccharides in rice depend on variety and quality, in particular, the grain size. Rice with poor quality tend to have higher monosaccharides content, in the form of simple sugar, and most notably glucose and fructose [47]. Furthermore, the amount of sugar in rice did not directly correspond to its quality. In contrast, medium grade rice, from *Bakwan* and *Sokan Pulau* obtain lower glucose content compare to both high and poor grade, where the latest is the highest one. In general, glucose content in *Bakwan* rice is higher than *Sokan Pulau* thus it tends to produce a higher risk for obesity and DM when consumed excessively. Besides glucose, fructose is another form of simple sugar that present in rice. While the concentration of fructose is not linear with the rice quality, the condition in *Bakwan* and *Sokan Pulau* rice differs. For the *Bakwan* rice, the concentration is lowest in poor-grade and highest in medium-grade quality. As for the Sokan Pulau, the concentration of fructose is following the trend of glucose, being highest at poor grade, and lowest in medium grade. Both simple sugars produced a relationship with the diet and economic condition of the people in Padang. Low-income or low-income family tend to have a higher rate of obesity and DM, understandably, due to the purchasing of poor grade rice, which have a higher glycaemic index. The PCA fail to separate between high and medium rice quality (Premium and Medium) for *Bakwan* cultivar, but successfully classify three quality grades for *Sokan Pulau* rice. The models developed for non-destructive evaluation of glucose have a correlation value of 0.968, 0.903, 0.990, and 0.934 for calibration and validation of *Bakwan* and *Sokan Pulau* rice respectively. Correspondingly, models for non-destructive evaluation of fructose in *Bakwan* and *Sokan Pulau* rice have a correlation value of 0.968 and 0.990 for calibration, and 0.904 and 0.934 for validation of respectively. The study opens the understanding of the relationship between rice variety and quality in responding to the dietary mitigation for preventing obesity and DM, in particular for the poor society.

ACKNOWLEDGMENT

The authors express their gratitude to Directorate General of Higher Education (DIKTI) and Universitas Andalas for providing the fund for this research through *Klaster Riset Guru Besar* research scheme, contract number. 36/UN.16.17/PP.RGB/LPPM/2018 signed on 23 April 2018.

REFERENCES

[1] DKP. 2015. The average rice consumption of Padang residents in 2015. Food Security Agency. The government of Padang, West Sumatera. Indonesia (in Indonesian).

[2] Labensky, SR, Hause, AM. 2003. On Cooking: A Textbook of Culinary Fundamentals. 3rd ed. Upper Sadle River, NJ: Prentice Hall, pp. 638.

[3] WKU. 2013. WKU BIO 113: Carbohydrates. http://bioweb.wku.edu/courses/.

[4] Whfoods. 2016. A New Way to Look at Carbohydrates. The world's healthiest food. The George Mateljan Foundation.

[5] Chidthaisong, A., Rosenstock, B., and Conrad, R. 1999. Measurement of Monosaccharides and Conversion of Glucose to Acetate in Anoxic Rice Field Soil. Appl Environ Microbiol. 65(6): 2350–2355.

[6] USDA. 2016. National Nutrient Database for Standard Reference Release 28. Basic Report: 20040, white Rice, medium-grain, raw. United States Department of Agriculture. USA.

[7] BPS. 2015. Consumption of Rice Per Capita in Indonesia: 2011-2015. Indonesian Central Bureau of Statistics. Jakarta, Indonesia.

[8] Abhijit V. Banerjee and Esther Duflo. 2006. The Economic Lives of the Poor. MIT Economics. Massachusetts Institute of Technology, Cambridge, Massachusetts. USA.

[9] Dinkes. 2014. Health Profile of Padang: 2014. Padang Health Agency. The Government of Padang. Indonesia (in Indonesian).

[10] Diskes. 2015. Health Profile of Padang: 2015. Padang Health Agency. The Government of Padang. Indonesia (in Indonesian).

[11] Diskes. 2016. Health Profile of Padang: 2016. Padang Health Agency. The Government of Padang. Indonesia (in Indonesian).

[12] Drewnowski, A., and SE Specter. 2004. Poverty and obesity: the role of energy density and energy costs. Am J Clin Nutr 79(1):6-16.

[13] Erik E. J. G. Aller, Itziar Abete, Arne Astrup, J. Alfredo Martinez, and Marleen A. van Baak. 2011. Starches, Sugars, and Obesity. Nutrients. 3(3): 341–369.

[14] FAO. 1997. Carbohydrates in human nutrition. (FAO Food and Nutrition Paper - 66). Report of a Joint FAO/WHO Expert Consultation. ISBN 92-5-104114-8.

[15] Hill JO, Melanson EL. 1999. Overview of the determinants of overweight and obesity: current evidence and research issues. Med Sci Sports Exerc 31(11 Suppl): S515–S521.

[16] WHO. 2015. Sugars intake for adults and children Guideline. World Health Organization. ISBN: 978 92 4 154902 8.

[17] Johnson, R.K., Appel, L.J., Brands, M., Howard, B.V., Lefevre, M., Lustig, R.H., Sacks, F., Steffen, L.M., and Wylie-Rosett, J. 2009. Dietary Sugars Intake and Cardiovascular Health: A Scientific Statement from the American Heart Association. The American Heart Association AHA Scientific Statement 120:1011-1020.

[18] Drewnowski, A., and SE Specter. 2004. Poverty and obesity: the role of energy density and energy costs. Am J Clin Nutr 79(1):6-16.

[19] Harvard. 2015. Glycemic index and glycemic load for 100+ foods: Measuring carbohydrate effects can help glucose management. Harvard Health Publications. USA.

[20] Karzan A. Omar, Botan M. Salih, Nahla Y. Abdulla, Basi H. Hussin, Shiraz M. Rassul. 2016. Evaluation of Starch and Sugar Content of Different Rice Samples and Study their Physical Properties. Indian Journal of Natural Sciences 6(36): 11084-11093.

[21] AOAC, 1990. AOAC Official Methods of Analysis (15th ed.). Association of Official Analytical Chemists, Washington, DC.

[22] Wani, I.A., D.S. Sogi, A.A. Wani, B.S. Gill, U.S. Shivhare. 2010. Physico-chemical properties of starches from Indian kidney bean (Phaseolus vulgaris) cultivars Int. J. Food Sci. Technol., 45 (2010), pp. 2176–2185.

[23] P.C. Williams, F.D. Kuzina, I. Hlynka. 1970. A rapid calorimetric procedure for estimating the amylose content of starches and flours Cereal Chem., 4 (1970), pp. 411–420.

[24] Ali, A., T.A. Wani, I.A. Wani, F.A. Masoodi. 2016. Comparative study of the physicochemical properties of rice and corn starches grown in Indian temperate climate. 15(1):75–82.

[25] Cherie D., Herodian S., Ahmad U., Mandang T., Makky M. 2015. Optical characteristics of oil palm fresh fruits bunch (FFB) under three spectrum regions influence for harvest decision. International Journal on Advanced Science, Engineering and Information Technology. 5(3): 104-112. doi:10.18517/ijaseit.5.3.534.

[26] Cherie D., Herodian S., Ahmad U., Mandang T., Makky M. 2015. Camera-vision based oil content prediction for oil palm (Elaeis Guineensis Jacq) fresh fruits bunch at various recording distances. International Journal on Advanced Science, Engineering and Information Technology 5(4): 317-325. doi:10.18517/ijaseit.5.4.542.

[27] Makky M., Herodian S., Cherie D., Ahmad U., Mandang T. 2012. Spectroscopy and photogrammetric techniques for assessing physicochemical properties of oil palm (Elaeis guineensis Jacq) Fresh Fruits Bunch (FFB). Proceeding of the Research Dissemination Seminar, p.1-11. Bogor: Agricultural University.

[28] Makky M., Soni P., Salokhe V.M. 2012. Machine vision application in Indonesian oil palm industry. Proceeding of the Asian Forum of 2012 CSAM (Chinese Society for Agricultural Machinery) International Academic Annual Meeting, p. 1-12. Hangzhou.

[29] Makky M., Soni P., Salokhe V.M. 2014. Automatic nondestructive quality inspection system for oil palm fruits. Int Agrophys. 28(3): 319-29. doi: 10.2478/intag-2014-0022.

[30] Makky M., Soni P. 2013. Development of an automatic grading machine for oil palm fresh fruit bunches (FFB) based on machine vision. Comput Electron Agric. 93: 129-39. doi: 10.1016/j.compag.2013.02.008.

[31] Makky M., Soni P. 2013. Towards sustainable green production: exploring automated grading for oil palm fresh fruit bunches (FFB) using machine vision and spectral analysis. International Journal on Advanced Science, Engineering and Information Technology. 3(1): 1-7. doi:10.18517/ijaseit.3.1.267.

[32] Makky M., Soni P. 2014. In situ quality assessment of intact oil palm fresh fruit bunches using rapid portable noncontact and nondestructive approach. J Food Eng. 120: 248-59. doi:10.1016/j.jfoodeng.2013.08.011.

[33] Makky M. 2016. Portable low-cost non-destructive ripeness inspection for oil palm FFB. Agric Agric Sci Procedia. 9(1): 230 – 40. doi: 10.1016/j.aaspro.2016.02.139.

[34] Makky M. Trend in non-destructive quality inspections for oil palm fresh fruits bunch in Indonesia. Int Food Res J. 23(Suppl): S81-S90.

[35] Makky M. 2016. Multi-modal Bio-metrics Evaluation for Non-destructive Age States Determination of Tomato Plants (Solanum lycopersicum). International Journal on Advanced Science, Engineering and Information Technology 6(3):349-355. doi: 10.18517/ijaseit.6.3.821.

[36] Makky M., Santosa, Putri R.E., and Nakano K. 2017. Nondestructive Evaluation of Simauang Paddy Grains with Different Moisture Contents By Means of Spectrophotometry. AIP Conf. Proc. 1813, 020002-1–020002-10; doi: 10.1063/1.4975940.

[37] Atkinson, F.S., Powell, K.F., and Brand-Miller, J.C. 2008. International tables of glycemic index and glycemic load values: 2008. Diabetes Care 31(12):2281-2283.

[38] Herrero, M., Cifuentes, A., Ibáñez, E., and Del Castillo, M.D. 2009. Advanced Analysis Of Carbohydrates In Foods. Department of Food Analysis, Institute of Industrial Fermentations (CSIC), Juan de la Cierva 3, 28006 Madrid, Spain.

[39] Ronald A. Holser. 2012. Principal Component Analysis of Phenolic Acid Spectra. ISRN Spectroscopy, vol. 2012, Article ID 493203, 5 pages, doi:10.5402/2012/493203.
[40] Duarte, L.F., Barros, A., Delgadillo, I., Almeida, C., and Gil, A.M. 2002. Application of FTIR Spectroscopy for the Quantification of Sugars in Mango Juice as a Function of Ripening. J. Agric. Food Chem., 50 (11), pp 3104–3111. DOI: 10.1021/jf011575y.
[41] F.J. Rambla, S. Garrigues, and M. de la Guardia. 1997. PLS-NIR determination of total sugar, glucose, fructose, and sucrose in aqueous solutions of fruit juices. Analytica Chimica Acta 344(1–2):41-53.
[42] Lijuan Xie, L., Ye, X., and Liu, D. 2009. Quantification of glucose, fructose and sucrose in bayberry juice by NIR and PLS. Food Chemistry 114(3):1135-1140.
[43] Mohsenin, N.N., 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.
[44] FAO. 1999. CODEX STAN 212-1999 pp.1-5.
[45] Williamson D. 2004. Study: high-fructose corn sweeteners partly responsible for the obesity epidemic. UNC Gillings School of Global Public Health. USA.
[46] Hall, K.D. 2008. What is the Required Energy Deficit per unit Weight Loss?. Int. J. Obes. (Lond). 32(3): 573–576. doi: 10.1038/sj.ijo.0803720.
[47] Makky M., Santosa, Putri R.E., and Nakano K. 2018. Nondestructive evaluation of Bakwan paddy grains moisture content by means of spectrophotometry. Journal of Physics: Conference Series. 985:012012. doi :10.1088/1742-6596/985/1/012012