Effect of Sugar Concentration on Gelling Properties of Pectin from Malaysian Banana Peels (Musa Acuminata × Balbisiana)

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Abstract:- Gelation has sought to found every hydrocolloids' function. Traditional method of pectin extraction from underutilized banana waste is significant in food industry to tackle the food security issue. The effect of sugar concentration (20.8%, 27.7%, 41.6% and 48.6%) on gels' characteristics were investigated after the gel was efficaciously fabricated with the ratio of 1:08 (banana peel: water). For spreadability Line Spread assay, it was reported that increasing the percentage of sugar has decreased the distance of gel spread. There was a significant decrease (P<0.05) in the gel tenderness as the percentage of sugar increase. Similarly, the moisture content and water activity for gel were significantly reduced as the amount of sugar amplified at (p<0.05). All the four formulations showed a tremendous differences for color and texture analysis. From this study, this research managed to prove the capacity of pectin from banana peel in upholding the watermelon jam.

***Keywords**:- Banana, Sugar Concentration, Gel Formation, Pectin.*

I. INTRODUCTION

Pectin, a polysaccharide composing of D-galacturonic acids linked with α-1,4glycosidic bonds (Fig. 1). The highest concentrations of pectin are found in the middle lamella of cell wall, with a gradual decrease as one passes through the primary wall toward the plasma membrane [1]. Some of its galacturonide units are esterified as methyl galacturonate, whose extent is reported as degree of esterification (DE) or methyl esterification degree (MED) [2].

Since the earliest study, pectin could be obtained from various sources [3-4] and has diverse functional properties. In fact, pectin has always being acknowledge to assist very much in the gel formation under specified conditions [5]. The high-methoxyl (HM) pectin is pectin gel which is extracted in a normal method and has more than 50% esterified acid units, while the low-methoxyl (LM) pectin is pectin gel where the extraction process has to undergo modification or continued acid treatment that will yield pectin with less than 50% methyl ester groups [6]. The gelling property makes pectin available to be used in food industries e.g. jam, jelly, emulsion stabilizer and thickener in sauces. Pectin can also be used in medicine as a fibre source, a supplement to lower cholesterol and increase immunity or as dentistry adhesive [2] and [7]. Pectin, with better quality characteristics, is obtained from wet fruit residues, since pectin is a heat labile material and quality is lost in pomace drying process. However, apple pomace and citrus peel, in the wet state, are very perishable, especially due to microbial activity. Molds infestations could produce pectin-degrading enzymes (i.e., pectinases), which render pectin in the raw material unacceptable for food uses [8].

Pectin has been mainly used as a gelling agent in jam and jellies. Malaysia imports several tons of pectin each year, although there is a vast resource of agricultural products and agro wastes which can be used to produce pectin. Malaysia Agricultural Research and Development Institute [9] revealed that Malaysia produces 535,000 metric tons of bananas per year with 40 per cent of the total weight of the fruit being wastes that can be used to extract pectin. Sugar plays an important role in gel formation particularly for the removal of water shell from pectin. It is estimated that around 65% of sugar concentration is needed for obtaining an optimal gelling reaction.

Bananas are considered as one of the most important tropical fruits in the world market. The banana fruit is utilized by livestock and is eaten as fresh fruit by man when it is ripe. However, the peel of this fruit is often thrown away. Banana fruit peels constitute a significant quantity of wastes produced from banana processing, which is equivalent to 40% of the total weight of fresh banana. The chemical compositions of banana peels that are rich in dietary fiber with 50% on a dry matter (DW) basis, proteins (7% DW), essential amino acids, polyunsaturated fatty acids and potassium [10] allegedly need to be exploited. However, in Malaysia these peels are left as solid waste at large expense and are not being used for any other purposes. Thus, in this research, the gel formation from banana peel pectin was studied since banana peel is an enormous waste from stalls and food processing industries in Malaysia. The purpose of this research was to extract pectin from *Musa acuminata* × *balbisiana* peel and study the effect of sugar on gel characteristic.

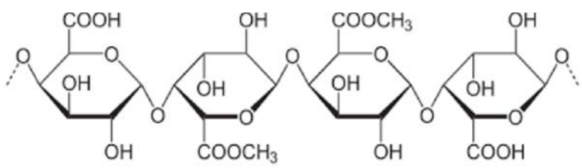

Fig 1:- Polygalacturonic acid chain of pectin (Herbstreith and Fox, 1998)

II. MATERIAL AND METHOD

A. Sample Collection

The ripe *M. acuminata* × *balbisiana* (AAB Group) peel (near to ripe) were obtained from a stall at Anggerik apartment at Nilai, Negeri Sembilan. The peels were prepared according to the research by [11]. The fruits were washed thoroughly to remove any adherence dirt and dust and then peeled.

B. Extraction of Juice

The peels were cut into small pieces, weighed, heated with water at temperature 100º C for 20 minutes and reduced to simmering temperature for 5-10 minutes until peels tender. The extracted juice was being filtered through cheesecloth. Fig. 2 shows the step involved in extraction of pectin juices.

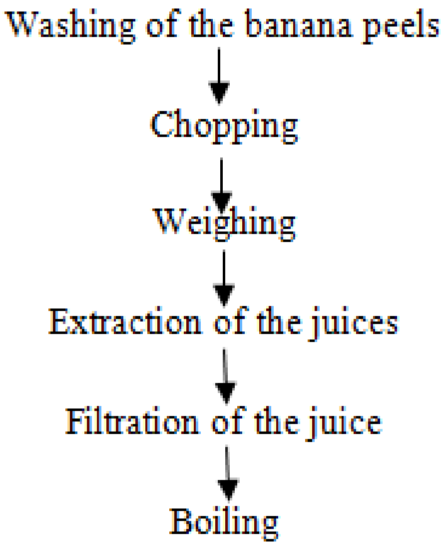

Fig 2:- Flowchart for the extraction of Pectin Juices

Five formulations were made to determine the ratio of banana peel to water for extraction. The different proportion of banana peels and water used to extract juice that is reported to contain pectin is presented in Table 1.

Formulation	Banana Peel (g)	Water (ml)	Ratio of banana peel to water
1	242	484	1:2
2	428	214	1:0.5
3	176	176	1:1
4	190	152	1:0.8
5	183	128	1:0.7

Table 1:- Formulation of Extraction of Pectin Juice

C. Production of Gel

The yield of the juice was measured using graduated cylinder, poured into a saucepan and boiled with sugar, citric acid until dissolved and the temperature indicated 4.4^{O}C above boiling point. The gel was transferred into a container and was set to cool. This study focused on the characteristics of gel extracted from banana peels added with water, sugar and citric acid. The citric acid used in this study was from natural source which was from lemon juice. The materials used have its own function to determine the characteristics of the gel. The study was done to observe the effect of sugar on the tenderness, the colour, the texture, the spreadability, moisture content and water activity of gel. The control and four formulations of gel with different percentage of sugar is presented in Table 2.

Formulation	Juice extracted %	Sugar content %	Citric acid %
Control	100	30	15
1	100	30	15
2	100	40	15
3	100	50	15
4	100	60	15

Table 2:- Formulation of Pectin Gel

D. Analysis of Gel

E. Determination of Gel Spreadability

The spreadability of the gel was determined by using the Line Spread Test [11]. Line Spread Test is a portable tool that determines the flow of the gel. A line spread test was used with concentric circles spread 0.5 cm apart from 0.5 cm to 3.5 cm radius. The test was carried out by pouring the gel at the centre of the line spread tool. Measurement of the gel spread was taken and recorded.

F. Determination of Gel Tenderness

The tenderness of the gel was measured by using Percentage Sag. The method was based on measurement of percentage sag occurred when a test gel is removed from its supporting container and inverted upon a glass plate [12]. The percentage (%) Sag was determined using the calculation below:

% Sag = (molded height-unmolded height ÷ molded height) × 100

G. Colour measurement of Gel

Colour measurement was carried out by Labscan XE Hunter Lab system colorimeter (Hunter Associates Laboratory. Inc. Reston, VA., USA). The chromatometer was standardized by white and black chromatic reference tile before analyzed sample. The sample was placed in the transparent glass cup and cover with black cup. Hunter Lab colorimeter gave results in three different colour units: lightness (L*), redness (a*) and yellowness (b*). The average colour measurement was recorded.

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H. Determination of Gel Texture

A Texture Analyzer Stable Micro System Ltd was used to determine the cohesiveness, viscosity, consistency and firmness of pectin gel. The probe used was 0.5 Cylinder Probe (P/0.5).The tests were performed by probe pressing the gel. The force-time curve was recorded and analyzed using the software Texture Exponent 32 (Surrey, UK).

I. Determination of Water Activity

The water activity of gel was determined by using Aqua Lab model TE (Decagon Devices, Pullman, Washington, USA). Sample was put in the cup and entered into the water activity meter. The water activity of gel was measured and recorded.

J. Moisture Content

One gram (1 g) of gel from each formulation was weighed and placed into a metal dish. The moisture content of gel was measured by using moisture analyzer with temperature 160^{0}C.

K. Making Jam using Gel form from Banana Peel

Gel form from banana peel was used in the making of fruit jam. Watermelon was washed thoroughly and chopped into small pieces. The pulp was then weighed and was cooked in a stainless pan with constant stirring to avoid scorching. Sugar and pectin extracted from banana peel were added and boiled vigorously. Citric acid was added when the mixture was thick [13].

L. Statistical Analysis

The results were determined in triplicate measurements. The data obtained were analyzed with Minitab (16.2.1 version software). A one-way analyses of variance (ANOVA) was conducted to determine the significance difference between each formulations. Any value that was considered significantly different ($P \leq 0.05$) was subjected to Tukey's method at confidence level 95%. All data were expressed as means ± standard deviation.

III. RESULTS AND DISCUSSION

A. Pectin Gel Spreadability

Line spread test is a measurement of viscosity of gel [11]. It was used to measure the flow distance of the thickened fluid, in centimetres, across a flat surfaces. The distance of gel flowed was read immediately after the elapsed time. The spreadability of gel formulations is presented in Table 3.

Formulations	Spreadability (cm)
Control Formulation	2.0
Formulation 1	2.0
Formulation 2	1.5
Formulation 3	1.0
Formulation 4	0.5

Table 3:- Spreadability of Pectin Gels

Gel was made from the strained juice of fruit. It should hold its shape but be soft enough to spread. From Table 3, the result showed that all gel was able to spread. Formulation 1 had the longest distance of line spread test because it contained less sugar that made it a thin liquid. Low amount of sugar resulted in a syrupy gel [14]. In contrast, Formulation 4 had the shortest distance for line spread test. Formulation 4 did not flow too much compared to other formulations. This was due to high amount of sugar, which resulted in liquid but a stiff gel. Sugar draws water out of the fruit and forms chemical bonds, which bind the water molecules to the sugar molecules [15]. The greater the amounts of sugar present in the gel the less water to interfere with bonding and crystal formation. The result is a very firm gel [16].

Table 3 showed that as the percentage of sugar increased from Formulation 1 to Formulation 4, the flow distance of the gel became shorter. The thinner the viscous liquid being tested, the higher the score of line spread test which meant the less thick liquid spread at longer distance compared to thick liquid. This showed that the different percentages of sugar affected the spreadability of the gels. The spreadability of control gel was 2.00 cm and it was the same with the Formulation 1 as they had same percentage of sugar even though apple is a high pectin fruit while banana peel has low pectin contents. The spreadability of apple ranges from 2.00 to 3.00 cm depending on the percentages of sugar. Frey (2009) studied that the high sugar concentration for apple pectin did not make the gel to spread.

B. Gel Tenderness

The gel tenderness was determined by using percentage of sag. The analyses for each sample of the formulation were done in triplicates to determine the percentage sag of gels. The average was calculated and the data is presented in the following Table 4 and Fig.3.

Formulations	Percentage of Sag (%)
Control formulations	5.62±0.03
Formulation 1	5.74±0.00
Formulation 2	4.86±0.01
Formulation 3	4.61±0.06
Formulation 4	3.12±0.06

Table 4:- Percentage Tenderness of Pectin Gels

Fig 3:- Graph of tenderness of gel

For the gel tenderness, the test statistic had a p-value of 0.00. Since the p-value was lower than α = 0.05 at 95% confidence interval, the null hypothesis was rejected and the alternative hypothesis was accepted. Therefore, it could be concluded that the mean of gel tenderness among the four formulations have significant difference based on the percentage sag. Formulation 1 has the highest amount of percentage sag because the gel formed was semi-solid and the gel dropped when the percentage sag test was done. Formulation 4 has the smallest amount of percentage sag because it contained the highest amount of sugar that resulted in stiff gel that only dropped a little bit when percentage sag test was applied.

Too high sugar concentration could cause water to be removed through osmosis and resulted in hard gel [17]. The increased sugar concentration resulted in decreased water available to keep pectin from interacting. The result increased gelling and possibly some crystal formation due to the lowered water concentration. However, if the amount of sugar was too low, the percentage sag of the gel might be higher result in the gel could not hold their form and dropped too much because it became concentrated liquid [18]. Figure 2 showed that as the percentage of sugar increased in each formulation from 30% to 60%, the percentage sag of gel decreased.

From Table 4, the percentage sag of control was 5.62±0.03 that indicated the gel was soft. The percentage of sugar in control was the same with formulation 1, which was 30%. Control formulation which was apple, was a high pectin fruits. Frey (2009) revealed that the high pectin fruits demonstrated the firmest gel when the sugar concentration was doubled.

C. Color Analysis

The data for color L*, a* and b* values were statistically analyzed. Color values were recorded as L* value represents 0 (black) to 100 (white). The a* value changed from – a* (greenness) to +a* (redness) while the b* value changes from –b* (blueness) to +b* (yellowness). Table 5 and Fig. 4 showed the color measurement of pectin gels.

Color	Control	F1	F2	F3	F4
L	33.69 ±1.91	45.63 ±0.14	46.47 ±1.26	50.47 ±0.61	41.80 ±1.16
a	1.09 ±0.77	8.36 ±0.06	6.37 ±0.25	7.02 ±0.16	5.04 ±0.21
b	18.40 ±1.94	36.07 ±0.53	29.5 ±2.92	30.26 ±1.38	27.64 ±1.88

Table 5:- Color Measurement of Pectin Gels

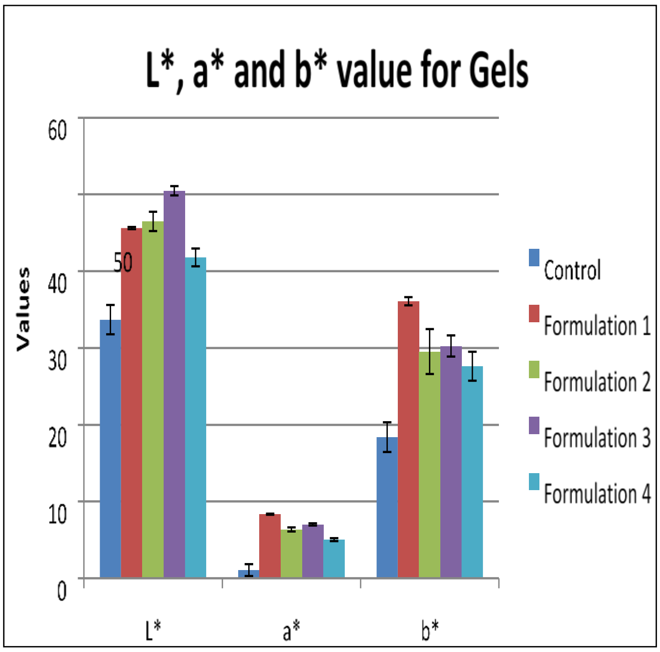

Fig 4:- The L*, a* and b* values for gels

According to Table 5, there was significant difference among the gels' colors of the formulations. The L* values observed in this study ranged from 41.80 to 50.47. Statistical test showed that there was significant difference between L* color of the formulations because p-value was less than αvalue=0.0.5. However, there was no significant difference between L* value between formulations 1 and 2. Formulation 4 was darker in color, as depicted by lower L* value than other formulations which was 41.80. The L* values observed in this study were due to caramelization that occur during heating.

For the gel color, it could be concluded that the mean of a* value among the four formulations had significant difference. The* values for gel formulations ranged from 5.04 to 8.36 and the b* values ranged from 27.64 to 36.07. Formulation 1 has the highest a* and b* value which indicated the gel color was more of redness and yellowness. Sugar contributes to product color and preserves jellies through its capacity to attract and hold water. By absorbing water more readily than other components, such as fruit, sugar prevents the fruit from absorbing water which would otherwise cause color to fade through dilution [19].

D. Texture Analysis

Table 6 and Fig. 5 represent the data obtained on textural properties of different gel formulation.

Texture	Control	F 1	F2	F3	F4
Firmness	27.20 ±2.00	548.76 ±1.80	684.6±0.93	725.69± 0.20	812.18 ±0.23
Consistency	52.66 ±4.18	727.52 ±2.38	1236.91 ±2.00	2761.72 ±0.74	945.33 ±0.31
Cohesiveness	- 8.39± 0.27	- 170.05 ±2.47	- 128.67± 2.64	- 43.95±3.38	- 63.27± 0.33
Index of Viscosity	- 19.94 ±2.7	- 70.89± 0.66c	- 58.87±1.97	- 125.87± 0.85	- 22.91± 0.56

Table 6:- Texture of Pectin Gels in Each Formulation
F= Formulation

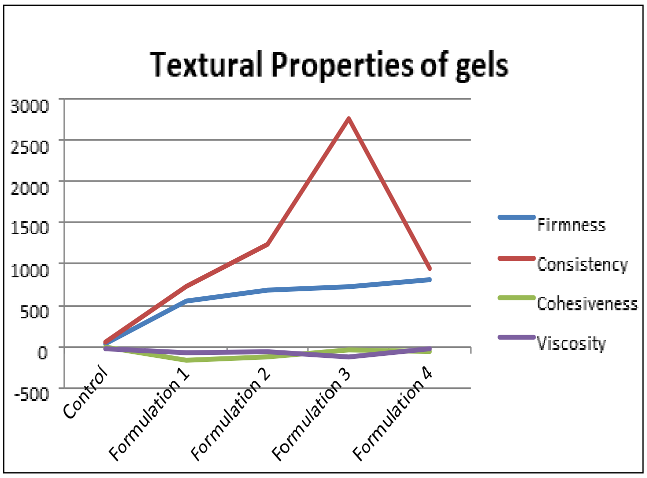

Fig 5:-The textural properties of gels

The texture properties of formulations are an important parameter in optimization of topical formulations. The effects of different amounts of sugar on the texture analysis parameters firmness, consistency, cohesiveness and viscosity for gels were shown in Table 6. Firmness is when the product displays a slight resistance to deformation. A firm product describes one that is moderately resistant to deformation. For the firmness parameter in the textual analysis, as the percentage of sugar increased from formulation 1 to formulation 4, the firmness of gels also increased. The low pectin fruit had the firmest gel when the sugar was added (Frey, 2009).

The sugar concentration was crucial in the gel formation. The role of the sugar is to pull the water molecules away from the pectin so that it could begin to bind together (Frey, 2009). When the sugar concentration was too low, the gel would not be able to form because the pectin molecule would be surrounded by water and unable to make contact with each other. However, if the sugar concentration was too high the solution begin to crystallize and a hard candy would be formed (Frey, 2009). This was the reason why the formulation 4 which has the highest amount of sugar, has the highest value of firmness.

The p-value for the firmness parameter from the statistical data showed a significant difference in firmness of the gels as the p-value was less than 0.05. For consistency parameter of gels textural properties analysis, as the percentage of sugar increased from formulation 1 to formulation 3 the consistency increased. Similar results were found in the kiwi spread products in which the higher the sucrose percentage in the sample the higher the consistency the sample had [20]. However, at formulation 4, the consistency of the gel decreased. This might be due to high sugar concentration in formulation 4 that cause sugar to crystallize and affected the consistency of the product [21]. In the manufacture of jam, marmalade and jelly, it is important to strike the correct balance between sugar, pectin and acid. Sugar's ability to gel when combined with pectin is vital to the consistency of the product.

When combined with the fruit pectin and acids in the correct proportions, sugar brings the gel to the correct consistency. However, certain fruits with very low pectin levels may require added pectin in order to achieve the correct consistency.

Cohesiveness is the quantity that reflects the strength of the internal bonds making up the body of the sample [22]. Cohesiveness is also defined as the work done to break down the internal bonds in gel [23. Cohesiveness is often used as indices of the ability of gel to maintain an intact network structure [24]. The cohesiveness percentage of sugar in gel increased from formulation 1 to formulation 3, the cohesiveness also increased. The higher cohesiveness values corresponded to samples with a weak gel structure. The structure of a weak gel is mainly formed by temporary cross-links, which may be largely reformed after the applied stress is removed and hence it shows high cohesiveness [25]. However, the cohesiveness value of gel in formulation 4 was less than the cohesiveness value information 3, even though it has the highest amount of sugar. This was because when a strong gel was stressed beyond its elastic limit, permanent as well as temporary cross-links are irreversibly destroyed, and the gel becomes broken, hence it showed low cohesiveness. High level of sugar makes gels harder but less cohesive texture [26].

For the gel viscosity, the test statistic had a p-value of 0.00. Since the p-value was lower than $\alpha = 0.05$ at 95% confidence interval, the null hypothesis was rejected and the alternative hypothesis was accepted. Therefore, it could be concluded that the mean of gel viscosity among the four formulations have significant difference. Table 6 showed that the viscosity of gels increased as the percentage of sugar increased from formulation 1 to formulation 4. Sugar was one of the factors that affected the viscosity of gel other than pectin concentration and temperature. Change in viscosity was due to the presence of sugar [27].

Past study results showed that viscosity gradually increased with the increase in sugar concentration which means that sugar concentration plays an important role to maintain the viscosity. Earlier studies also showed that sugar type is important for pectin solutions and observed that sucrose formed the most rigid gels that give better texture to product [25]. Sucrose increases the viscosity of pectin solutions [28].

E. Water Activity

Water activity (a_w) of gel in different formulation is presented in Table 7 and Fig.6.

	Control	F1	F 2	F 3	F 4
Water activity (a_w)	0.7723 ±0.00	0.8038 ±0.00	0.8027 ±0.01	0.7601 ±0.00	0.7280 ±0.00

Table 7:- Water Activity of Gel in Each Formulation
F= Formulation

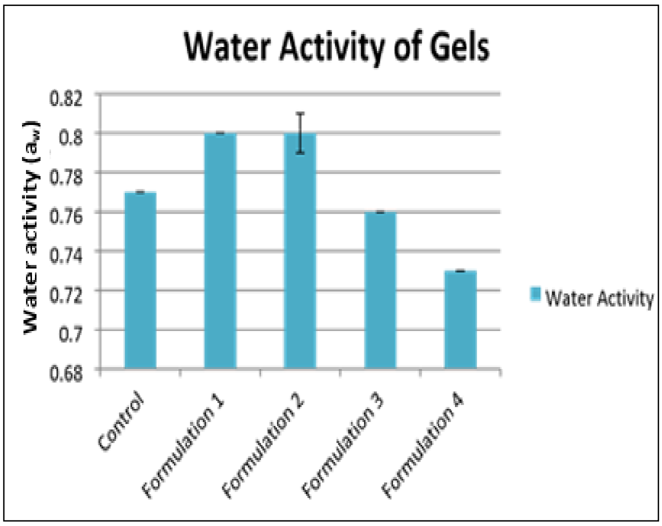

Fig 6:- Water activity (aw) of gels

Water activity is a measurement of the availability of water for biological reactions. Water activity is significant in the safety and in the physical properties of food such as texture, shelf life and the sensory properties [29]. From table 7, there was significant difference among the water activity of the formulations. Fig. 6. indicated the decreasing trend from formulation 1 (0.8038) to formulation 4 (0.7280). This showed that as percentage of sugar increased in the gels, they were less chance for microbial growth. Sugar is a good depressor of water activity. Sugar draws water out of the fruit and forms chemical bonds, which binds the water molecules to the sugar molecules. The bound water was held so tightly that it was no longer available to support the growth of several microbes [15]. In this way, sugar acts as a means of preservation against future microbial growth problem [30].

By observing the water activity of different formulation of gel, formulation 1 tends to have a short shelf life compared to other formulations as formulation 1 had the highest value of water activity. The water activity content of formulation 1 and formulation 2 was in the range with water activity content in commercial citrus pectin while water activities for formulation 3 and formulation 4 were lower compared to commercial pectin. Commercial citrus pectin water activities are in the range of so-called intermediate products, 0.80 to 0.85 (Zhao, 2007). These products are not self-preserved because the water activity values are not lower enough to control microbial growth or chemical reactions. In industry, chemical preservatives such as sorbate and benzoate salts can be used. If preservatives are not used, water activity can be complemented by the use of hermetically sealed containers and recommendations of refrigeration once the containers are opened (Zhao, 2007)

F. Moisture Content

The moisture content of gel for each formulation is presented in Table 8 and Fig. 7.

	Control	F 1	F2	F 3	F4
Moisture Content (%)	23.277 ±0.73	20.743 ±1.12	19.150 ±3.34	10.890 ±1.00	10.830 ±1.66

Table 8:- Moisture Content of Gels
F= Formulation

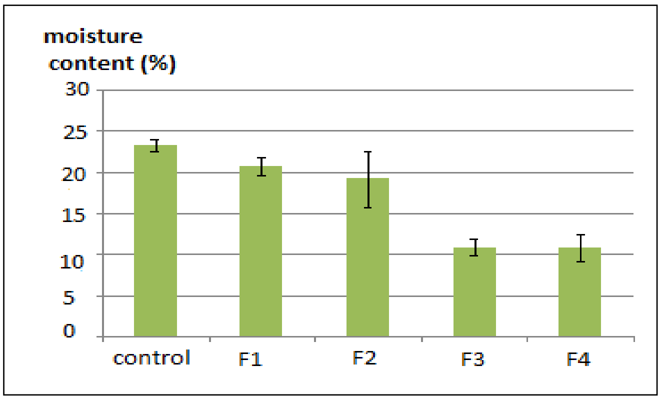

Fig 7:- Moisture Content

Based on the results shown above, as the percentage of sugar increased from formulation 1 to 4, the moisture content was decreasing. The moisture content in formulation 3 and formulation 4 did not vary significantly when compared with the moisture contents of commercial citrus pectin, which was 12.03%. Low moisture content is necessary for pectin for safe storage as well to inhibit the growth of microorganisms that could affect the quality due to the production of pectinase enzyme [31]. Sugar's ability to bind water in foods is based on the ratio between crystallized and dissolved sugars. Any change in this ratio during production or storage affects the amount of water that the food can bind. When sugar binds water, reactions that need water are delayed, hence, increase the product shelf life.

IV. CONCLUSION

The best ratio of banana peel to water for extraction of pectin was 1:08 as it was proved to successfully produced gel with addition of sugar and lemon juice. It was proved that the effect of sugar was significant on the characteristic of final products.

The different percentages of sugar in gel affect the spreadability of gel. Gels with higher percentage of sugar do not spread too much. For tenderness, gel with the lowest percentage of sugar has the highest percentage of sag which means the gel was the tenderest out of the four formulations. Formulation 4 has the darkest color among the four formulations as a result of the caramelization that occurs during heating process.

The different percentage of sugar had an impact on the gels textural properties. The water activity and moisture content of gels both showed significantly different between each formulation. Both water activity and moisture content decrease as the percentage of sugar increase.

Conclusively, pectin was successfully extracted from 'Pisang Tanduk' peel by using the direct boiling method. The different percentage of sugar affects the spreadability, tenderness, color, texture properties, water activity and moisture content of the gel formed from banana peel pectin.

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