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Effect of application of pectin and albumin crispiness properties and oil absorption of batter

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This study aimed to investigate the effect of pectin and albumin on the oil absorption rate and crispiness properties of batter and to develop batter that has low oil absorption rate and hold the crispiest texture. Six formulations R1 (6% pectin), R2 (10% pectin), R3 (6% albumin), R4 (10% albumin), R5 (6% pectin & 6% albumin), R6 (10% pectin & 10% albumin) together with two control KA and KB were produced. Samples (R3) showed a color that meets the needs of coatings based on the L *, a * and b * value in which both L * and a * values showed significant difference ($p<0.05$) with other samples in terms of brightness. Sample R3 and R5 showed the highest moisture content and lowest fat content for both crust and flesh. The differential scanning calorimeter (DSC) showed that the enthalpy of crystallization for samples containing combination of 6% pectin and 6% albumin (R5) was the highest compared to other samples as pectin and albumin formed strongest gel at that concentration. For the porosity, sweet potatoes coated with 6% pectin and 6% albumin (R5) was effective in protecting the cellular structure of sweet potato from damage during frying process. A batter with low oil absorption rate and most crunchy can be developed with the addition of 6% albumin and 6% pectin (R5) due to its characteristics as a gelling agent that helps to reduce the loss of moisture in the product and absorption of excessive oil.

Keywords: Pectin, albumin, crispiness, oil absorption

INTRODUCTION

According to Rungsinee (2011), the absorption of oil in fried food is related with the moisture content of food products. Moisture retention can be enhanced by adding batter to food products. This is explained by the strong interaction of hydrogen and water molecules while preventing the penetration of oil into food products and reducing oil absorption (Akdeniz et al. 2006). Generally oil is absorbed into the food during frying because the water content of the food evaporates and forms a porous area on the food surface to be filled (Andrew & Robert 2012).

The absorption of oil into food will result in the formation of carcinogenic acrylic (Sizer et al. 2002; Tareka et al. 2000). Frédéric et al. (2010) explain that the absorption of oil in fried foods can be reduced by the preparation of batter. The basic formulation of batter ingredients consists of either rice flour, wheat flour or corn flour (Shih et al. 2004). However, according to Becalski et al. (2003) among the factors contributing to the formation of acrylic are high processing temperatures and interactions between protein and carbohydrate components. Therefore, batter containing rice flour are widely used to reduce the additional acrylic that occurs during frying process.

According to Shih et al. (2004) additives need to be added to the formulation of batter ingredients to provide viscous properties of rice flour and improve frying properties. Several formulations with specific additives and new processes have been developed to produce low-fat products with the desired quality properties of fried food products. Kang et al. (2005), Maftoonazad and Ramaswamy (2008) agree that pectin and albumin are additives that can reduce oil absorption and improve the quality of fried food products.

Pectin and albumin have mechanical properties that control moisture levels and have low vaporization capacity (Sabina & Andrzej 2007). Both of these ingredients act as a reducing agent to prevent moisture loss in fried foods. Pectin prevents moisture loss by gel formation based on the degree of solubility while gel formation by albumin is due to the presence of abundant free sulfhydryl groups (Tanja 2015; Yan 2016). The formation of gels can prevent moisture loss while reducing the absorption of oil into fried food products (Elizabeth et al., 2009).

Most of the previous studies used pectin together with other polysaccharides such as carbosimethyl sellulose, arabic gum, xantan glue and others while albumin was tested with other proteins such as chitosan, gelatin and soy protein. The objectives of this study were to determine the effects of pectin (polysaccharide) and albumin (protein) at different concentrations (6% and 10%) on the rate of oil absorption and improve the crispiness properties of batter. This study was also conducted to develop batter with low oil absorption rate and a crisp texture. In addition, the effect of solubility in aqueous solution of 0.5% calcium chloride ($CaCl_2$) will also be tested. Sweet potatoes were used as carriers in this study.

MATERIALS AND METHODS

Materials

For batter preparation for fried sweet potatoes, the raw materials needed are rice flour, wheat flour, sugar, salt, cooking oil, pectin and albumin powder. All of these ingredients are available from Speedmart and Yummie Bakery Sdn. Bhd, Bangi Selangor. The albumin and pectin provided are in the form of powders and grade foods. Water is supplied by the Faculty of Science and Technology's Plant (UKM, Bangi Selangor). The batter is based on basic formulations with slight changes obtained from Siti and Yusof (2012).

Experimental design

A total of eight formulations are used and the experimental design is shown in Table 1. The formulation produced is based on the formulation with slight changes obtained from Siti and Yusof (2012).

Table 1 :Levels of addition of additives in the coated ingredients

Formulation	Dry mixture (g)	Pectin (g)	Albumin (g)	Water (ml)
KA	100	0	0	75
KB	100	0	0	75
R1	100	6	0	75
R2	100	10	0	75
R3	100	0	6	75
R4	100	0	10	75
R5	100	6	6	75
R6	100	10	10	75

* The dry mixture consists of 75g of rice flour, 15 g of wheat flour, 5g of salt and 5g of sugar.

Preparation on sweet potatoes (Pahade & Sakhale 2012.

Before frying, the sweet potato is peeled off and the flesh are cut in half vertically. All sweet potatoes were blanched in water at 85ºC for 5 minutes and washed in cold water for 5 minutes and dried at 150ºC for 3 minutes using a convection oven to reduce the moisture content of the sweet potato.

For control samples KB, no chemical treatment was applied to the sweet potato after drying. For samples KA, R1, R2, R3, R4, R5 and R6 sweet potatoes were immersed in aqueous solution of calcium chloride ($CaCl_2$) at a concentration of 0.5% for 2 minutes for pectin and protein binding proporties.

Method of preparation basic formulations of dry mixture of batter (Siti & Yusof 2012)

The batter are prepared by mixing the dry mixture with water at a ratio of 4:3 (dry mixture: water). For the addition of pectin and albumin powder, the flesh was divided into eight treatments (Table 1). Pectin powder or albumin powder was dissolved in 100 ml distilled water for 2 minutes. The sweet potato was immersed in aqueous solution and dried at 150ºC for 3 minutes using a oven before dipping in the batter and frying.

Frying process

The sweet potato is deep fried using palm cooking oil at a temperature of 180ºC for 3 minutes. All samples were fried and dried at room temperature before analysis.

PHYSICAL ANALYSIS

Texture analysis (AOAC 1990)

Sample texture profiles were analyzed using the AGS-J tool, the Shimadzu Twin-Column Texture Analyzer 500N (Japan). Samples were placed on the probe and compressor before being pressed onto the sample surface. Maximum power is measured when the sample surface is pressed. Measurements were performed on three different sections of the sample and the average readings were recorded.

Color analysis

The Minolta chroma meter (model DR-400 Trimulus Color Analyser, Japan) was used to determine the colour of the sample. This tool provides three values: L * reading representing brightness degree, a * representing redness degree and b * representing yellowish degree. Average readings were obtained after measurements were performed on three different sections of the fried sweet potato sample.

Determination of moisture content

The oven drying method (AOAC 1984) was used to analyze the moisture content of the crust and flesh sections. Samples on the crust were extracted by scraping the surface of the fried sweet potato sample with a knife and crushed using a blender to make it homogeneous. A 0.5g sample was placed on a nickel tray and heated at 105˚C overnight and then remove from the oven and cooled in a drying jar for 30 minutes. The moisture percentage is calculated using the formula below

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} \times 100\%$$

W1 = Weight of sample before drying
W2 = Weight of sample after drying

Analysis of fat content

The Soxhlet method is used to determine the fat content. Fat content analysis was performed on both crust and sweet potato flesh with three replicates. A total of 1.0g of the sample was dried using an oven-drying method at 105˚C for 16 hours. Samples were crushed, weighed, and wrapped in filter paper and embedded in extruded jars containing pores to allow for hexane flow. 50ml of hexane is poured into an extraction cup.

At 130˚C, the heater is adjusted for continuous boiling. The tap water needs to be opened to cool the condenser. Samples were allowed to boil for 15 to 20 minutes, reflux for 30 to 40 minutes and cooled for 10 minutes. Samples and containers of soxhlet were dried in an oven for 30 minutes at 100˚C. The sample is then removed and cooled in a drying jar and data were recorded.

Thermal analysis

Calorimeter Scanning Differential (DSC)

Mettler Toledo DSC (Model 822e,

Switzerland) with StarE computer software was used to test crystallization enthalpy. After the sweet potato is fried, the samples are cooled to room temperature until the oil has fully crystallized. The crust of fried sweet potato is separated from the contents and grinded with a Panasonic grinder (MX-AC400 model, Japan). DSC module, gas (40 ml / min) and coolant are turned on. A total of 10 mg of the sample was placed in an aluminum tray. The tray was closed with a lid before being put into the furnace and analyzed.

The temperature was maintained at 40ºC for 5 minutes before being cooled to -60ºC for 5 minutes as well. Then the sample is heated to -60ºC until the temperature reaches 40ºC. Heating and cooling rates of 10◦C / min were used. DSC icon is printed. The crystallization curves of the oil samples are reported.

IMAGE ANALYSIS (TABLETOP MICROSOPTION)

The crust of fried sweet potato is scraped and cut at a size of 1.5cm × 1.5cm. Then the layer was placed in a freezer for 24 hours. The dried samples were observed using a Hitachi tabletop microscope (model TM-1000, Japan) at × 50 magnification. The images taken are converted to gray with a gray-level image (8bits), followed by a threshold method to segment the image so that binary images have a clear black-and-white contrast. The percentage of porosity for each sample was determined with this software.

STATISTICAL ANALYSIS

Proximate and physicochemical analysis data were tested by analysis of variance (ANOVA) at 95% confidence level ($p < 0.05$) using Minitab software. A total of three replications were performed for proximal, physicochemical and thermal analysis. The data obtained were averaged and expressed in the mean ± standard deviation. Correlation analysis was also performed to see the relationship between moisture content and fat content.

RESULTS AND DISCUSSION

PHYSICAL ANALYSIS

Texture Profile

Referring to Figure 1, there were significant differences ($p > 0.05$) of the hardness levels between all samples with control A and B. Samples R1 and R6 and also R2, R3 and R4 shows no significant differences ($p > 0.05$) respectively. This is due to some of factors that influence the changes in texture in batter and crust such as moisture loss, protein degradation and starch deposition (Loewe 1993).

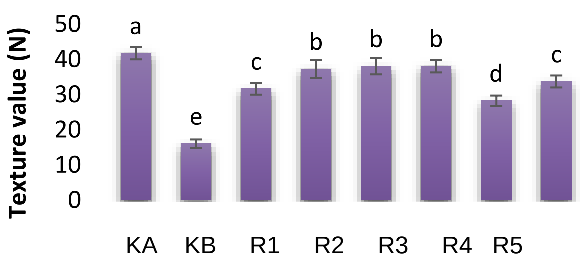

Figure 1: Mean texture of fried sweet potato prepared with the addition of different level of pectin and albumin.

[a-e] Different alphabet shows significant differences ($p < 0.05$)

The hardness level of the KA sample is highest. This indicates that the crispiness of the KA sample is lower than the other samples whereas for KB which is a batter sample that has been marketed, the degree of hardness shown is low and the crispiness level of batter is high.

The differences shown by the KA and KB samples were influenced by the blanching process. Blanching can helps to improve the color and texture of the sweet potato and can reduce oil absorption due to starch gelatinization on food products surfaces (Califano & Calvelo 1987). Calcium chloride is able to stabilize the tissue structure from damage during the frying process (Dorin, 2014). Calcium plays a role in binding to pectin or proteins and thus makes them more fragile and disrupts starch interactions. This could explain the results of the samples that added with pectin which is R1 and R2 where there was a significant difference ($p < 0.05$) between the two samples. However, excess protein can reduce the crispiness and increase oil absorption.

For sample R5 consisting of a mixture of 6% pectin and 6% albumin, there was a significant difference ($p < 0.05$) in all samples. This indicates that the R5 sample crispiness is not only affected by pectin but also to albumin. According to Andrew (2012) the rate of browning of fried products will increase as proteins contain more amino groups. This amino group reacts to the Maillard reaction. The increase in the rate of browning effects the crispiness and absorption of oil by fried foods. Overall, samples with low levels of hardness showed high crispiness properties of batter.

Colour

Based on Figure 2 for L * values there were no significant differences ($p > 0.05$) for KA, KB, R2, R4, R5 and R6 samples. Whereas R1 and R3 samples showed significant differences ($p < 0.05$) with all samples. According to the frying guidelines by the National Edible Oil Distributors' Association (NEODA) (2013), high concentration of additives, prolonged coating time and insufficient oil flow can affect the colour change during frying. Based on the data obtained, the addition of 6% pectin (R1) and 6% albumin (R3) is the optimal percentage which will increase the brightness of the fried product.

R1 is a sample added with 6% pectin. Pectin is an effective hydrocolloid to slow down colour change. During the frying process, darker colour is result from prolonged oil degradation or frying (Krokida, Oreopoulu & Maroulis 2001). Therefore, the use of pectin can protect against degradation, oxidative stress as well as unwanted colour changes (Elizabeth et al. 2009).

For R3 samples added with 6% albumin, the colour brightness increased. According to Mohamed et al. (1988), the addition of ovalbumin to the batter increased the crispiness and colouration of the amine groups in the protein during the Maillard reaction. Furthermore, the blanching process by calcium chloride on the sample resulted in an increase in L * values.

The low a * value indicates the tendency to have green instead of red colour. The higher a* value indicates the Maillard reaction occurred. Based on Figure 2 there were no significant differences (p> 0.05) between KB, R2, R4, R5, and R6 samples but there were significant differences (p <0.05) with KA, R1 and R3 samples. This is because samples R1 and R3 are added with pectin and albumin at lower concentrations than other samples such as samples R6 with higher a * values. High protein content in batter will result in increased brown color.

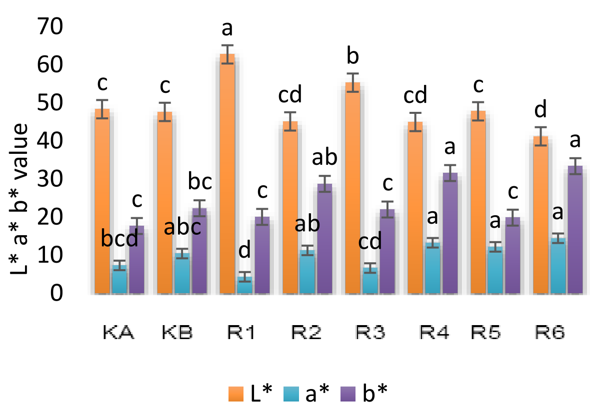

Figure 2: Mean color of fried sweet potato prepared with the addition of pectin and albumin.

[a-d] Different letters indicate significant differences (p <0.05)

The yellowish of the food product depends on the value of b *. Positive b * values indicate yellow while negative values indicate blue. As a result of the analysis results, all samples showed a positive b * value so all fried sweet potato were yellow. Based on Figure 2 there were no significant differences (p> 0.05) between KA, KB, R1, R3 and R5 whereas samples R2, R4 and R6 showed significant differences (p <0.05) with the other samples. This may be due to the higher concentration of pectin and albumin added as described in the value of a *. The increase in the value of b * gives more yellow in food products especially fried products (Krokida et al. 2001).

Based on the results of the analysis above, it can be concluded that the sample R3 shows the characteristics of the batter that meets the objective requirements based on the values of L *, a * and b * where the value of L * and a * shows a significant difference (p <0.05) with the sample other in terms of brightness and simple tendency to green or red.

Moisture content

Moisture content of crust showed that R3 and R5 samples differed significantly (p <0.05) with KA, KB, R1, R2, R4 and R6 samples. Sample R3 was added with 6% albumin while R5 sample was added with 6% pectin and 6% albumin. This difference may be due to the 6% albumin content.

According to Ansarifar, et al. (2012) reduction in moisture loss can be attributed to the resulting gel and the ability to form a film coating from albumin. The albumin protein is made up of half the ovalbumin. It is a fraction containing a group of free sulfhydryl (SH). At high temperatures during the frying process, the number of SH groups increases and the concentration of the film layer increases. The increase in SH surface concentration is important because when exposed to air the SH group will be converted to S-S intermolecular bonds by the oxidation reaction and sulfhydryl-disulfide exchange. Therefore, the formed film produces a hard crust to prevent water loss.

Referring to Figure 3 there were no significant differences (p> 0.05) for samples R1 and R2. Samples R1 and R2 were samples added with different percentages of pectin content of 6% and 10%, respectively. According to Indrani, et al., (2014) studies, most hydrocolloids are hydrophilic. This property limits moisture resistance and therefore, this coating material has a higher moisture content than non-pectic coating.

Despite sample R6 and R2 have same amount of pectin added, R6 shows significant differences (p <0.05) with R2. This proves that the addition of excess albumin disrupts the role of pectin.

For the flesh section, no significant differences (p> 0.05) were shown for all samples. This may be due to factors such as the same treatment given by the blanching method at 85 ° C for 5 minutes.

Overall for the crust, R3 and R5 showed significant differences (p <0.05) with the other samples and were suitable for development as a batter that meets the objective requirements as it is able to maintain high moisture even after evaporation process. As for the flesh layer there was no significant difference (p> 0.05) between all samples and controls. This indicates that all formulations have the same moisture content as controls.

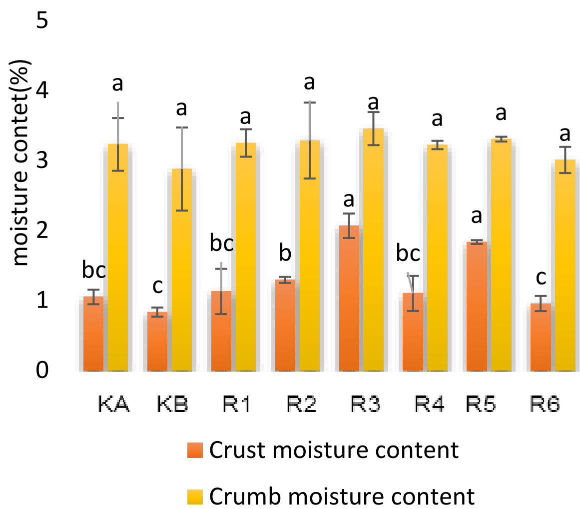

Figure3:Mean moisture content of fried potatoes prepared with the addition of pectin and albumin

a-b a-b Different letters indicate significant differences ($p < 0.05$) at different level.

Fat content

Based on Figure 4 for the crust , samples KA, KB, R3, and R6 showed significant differences ($p < 0.05$) with the other samples. R3 added with 6% albumin and has the lowest percentage of fat content of only 5.49% while the highest percentage of fat content besides market controlled substances, KB was R6 sample of 15.10% added with 10% pectin and 10% albumin.

The low percentage of fat content in the R3 sample due to the natural nature of ovalbumin that is lipophobic (Kato & Nakai 1980). However, increasing the percentage of albumin may increase the percentage of fat content as shown in sample R6. Sample R6 consisted of 10% addition of pectin and 10% albumin. Similar to the texture and moisture content, the process of emulsifying water and oil into fried products increases due to excess protein content.

R1 and R4 showed no significant differences ($p > 0.05$). R1 and R4 received 6% pectin and 10% albumin treatment respectively. The addition of 6% pectin and 10% albumin was able to reduce the absorption of oil compared to the sample in the market, KB. R1 and R4 have similarities where at 6% and 10% percentages, they can form a gel layer during frying. This can reduce moisture loss.

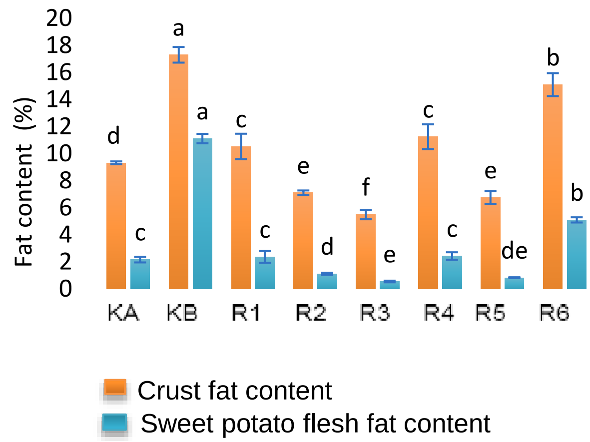

Figure 4: Mean fat content of sweet potato with the addition of different pectin and albumin level

a-e Different alphabet shows significant differences ($p < 0.05$)

For the sweet potato flesh contents, there was no significant difference ($p > 0.05$) in terms of fat content of the samples KA, R1 and R4. Samples R1 and R4 containing 6% pectin and 10% albumin shown that both have the strength to form a layer to prevent oil penetration. No significant differences ($p > 0.05$) were shown between sample R2 and sample R5, as well as between sample R3 and sample R5.

Furthermore, according to the study of Suzana et al. (2004) oil content in fried products is influenced by the blanching procedure. All samples R1, R2, R3, R4, R5 and R6 were blanched in 0.5% calcium chloride solution. This is because calcium chloride ($CaCl_2$) is able to stabilize the tissue against damage that occurs during the frying process.

It can be concluded that high moisture content and low oil content can reduce oil absorption rate. Based on the analysis above, for the crust layer R3 showed significant differences ($p < 0.05$) with the other samples. However, for the flesh layer only samples R3, R5 and R2 showed significant differences ($p < 0.05$). Therefore, R3 is suitable to develop as a batter because of its low fat content and high moisture content.

THERMAL ANALYSIS

Differential Scanning Calorimeter (DSC)

From Table 2, the obtained DSC peak temperature did not differ significantly from the values obtained by the Ng and Oh (1994) study. Therefore, the crystallization peak in the cooling curve of Figure 5 is the crystallization peak for palm oil.

Table2: Values of crystallization enthalpy, onset temperature, peak temperature and sample endset temperature

Sample	Crystallization enthalpy (Jg^{-1})	*onset* temperature (°C)	Peak temperature (°C)	*Endset* temperature (°C)
KA	6.23 ± 1.64^{b}	5.42 ± 1.08^{a}	1.78±0.61^{a}	-12.03± 0.88^{a}
KB	11.09 ± 0.^{46ab}	5.70 ± 1.89^{a}	2.39± 2.34^{a}	-13.26± 2.45^{a}
R1	6.00± 0.21^{b}	5.51 ± 1.74^{a}	2.46±1.54^{a}	-13.69 ±3.78^{a}
R2	6.50 ± 0.40^{ab}	4.98 ± 0.81^{a}	0.88±0.11^{a}	-16.17± 0.01^{a}
R3	10.40 ± 4.84^{ab}	5.12 ± 0.70^{a}	0.88 ± 0.23^{a}	-15.43± 0.08^{a}
R4	4.94± 0.31^{b}	5.91 ±1.08^{a}	1.46 ± 0.11^{a}	-13.20± 2.10^{a}
R5	14.02 ±4.77^{a}	5.20 ±1.03^{a}	1.04 ±0.47^{a}	-17.48± 4.11^{a}
R6	9.51 ± 5.98^{ab}	5.80 ±1.23^{a}	2.47 ± 1.78^{a}	-12.64± 3.60^{a}

$^{a-c}$ differences in the same column showed significant differences ($p < 0.05$).
Data with three readings are expressed as the mean ± standard deviation.

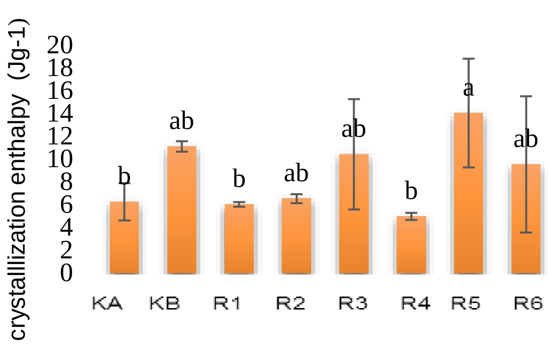

Figure 5: The frying crystallization enthalpy prepared with the addition of different level pectin and albumin.

$^{a-b}$ Different letters indicate significant differences ($p < 0.05$)

The lowest crystallization enthalpies were indicated by sample R4 where the sample was added with 10% albumin. This showed an increase in excess albumin content resulting in lower crystallization enthalpy because the gel formed was less stable than the other samples. . Overall, the R5 sample was able to form a strong gel structure based on the highest crystallization enthalpy value compared to the other samples while R4 has low crystallization enthalpy value made the gel less stable.It can be concluded that R5 is a sample with optimum addition of pectin and albumin as the desired batter for this study.

MICROSCOPY

There were significant differences ($p < 0.05$) in terms of pore size of all samples. It is found that the pore area for the KB sample is largest while R5 shows the smallest pore area (Figure 6).

KB shows extensive cell separation and cell division due to large water migration and pore space including central lamina and wall cell damage (Singthong & Thongkaew 2009). This is because the KB sample was not added with albumin or pectin and was not given the treatment with calcium chloride ($CaCl_2$).

The addition of pectin and albumin at an optimum concentration such as 6% as shown in sample R5 retains moisture content in food. Therefore, the pore area was small in samples containing albumin and pectin. However, R4 sample in which 10% of the albumin is added leads to greater pore formation. This occurs because excess protein causes the process of emulsifying water and creates a larger pore where migration occurs between moisture and oil (Suhaila, et al., 1998). R1 sample proves that the addition of 6% pectin is an effective concentrate to protect the sweet potato from pore formation during the frying process. Overall the sample having smaller pore size and meet the objective in this study is sample R5.

CONCLUSION

For texture attributes, samples with low hardness showed high crispiness of batter. R5 shows the crispiness level that corresponds to the objectives of this study while for color attributes, sample R3 shows significant differences with other samples in terms of L * and a * values. For analysis of crust moisture content and flesh, R3 and R5 showed significant differences ($p < 0.05$) with other samples. Based on the analysis of fat content, for the R3 crust layer showed significant differences ($p < 0.05$) with the other samples but for the sample flesh, R3, R5 and R2 showed significant differences ($p < 0.05$).

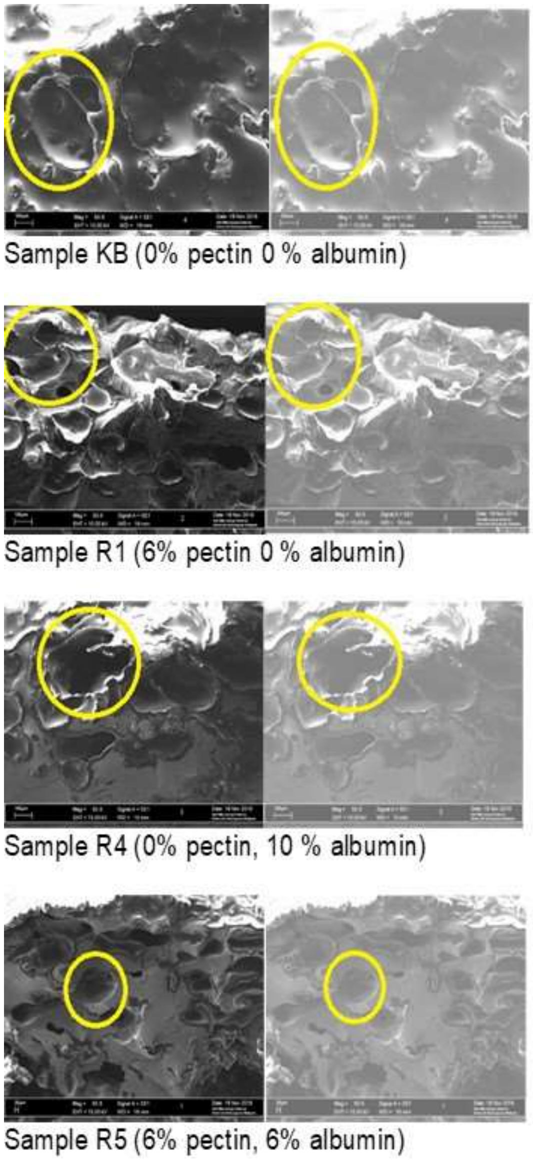

Figure 6: Sample surface images of KB, R1, R4 and R5 under magnification × 50

The analysis of the Differential Scanning Calorimeter (DSC) showed that R5 samples were able to form a strong gel structure based on the highest crystallization enthalpy values compared to other samples. Based on the photomicrograph of the sample, sample R5 with a smaller pore size meets the objective requirements. In conclusion, addition of pectin and albumin at a 6% (R5) proved to be the most effective in lowering oil absorption rates and enhancing the crispy properties of the batter as they form the strongest gels that prevent oil absorption.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Add contribution of each author (with abbreviated name) here. For example WEP designed and performed the experiments and also wrote the manuscript. AS and MR designed experiments and reviewed the manuscript. All authors read and approved the final version.

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