CHAPTER 4 – RESULT & DISCUSSION

From the research that had been done, the data and discussion are as followed.

4.1 Extraction of RS2

Extraction of RS2 were done using water alkaline extraction method. The process refers to previous study by Zhang et al. 2005 and Vatanasuchart et al., 2012 with some modification. Through 4 different modification applied, it is found that the fourth method shows the highest yield up to 49.6% . Methods and yields achieved are present in table 4.1

Table 4.1 Methods and Yield of RS 2 Extraction

No	Methods	Yield (from dry basis)	Condition of Starch
1	Fresh Banana + 0.05 N NaOH	33.33%	Clean and odorless starch
2	Fresh Banana + 0.05 N NaOH with constant stiring under high temperature	24 - 25 %	Clean and odorless starch
3	Dry banana + 0.05 N NaOH	15%	Unclean starch with unpleasant odor due to some fermentation process
4	Fresh banana + 0.1 N NaOH + constant stirring for 3 hours	32 - 45 %	Clean and odorless starch

Based on the experiment, there are some critical point in order to achieve higher yield of starch.. From the process, concentration of NaOH becomes the critical point that effect the yield of the RS 2 present. It is found that higher concentration of NaOH will increase the ability protein breakdown and release the starch granule from the gum inside the starch itself. When the concentration of the NaOH is too high there will be too much gum and result in a slimy slime where this slime is actually gum that comes from the unripe banana.

4.2 Characterization of Banana Starch RS 2

Banana Starch (RS2) achieved from the extraction process is characterized through proximate analysis. The result are then compared to result studied by Selvamani et al., 2009 which also do proximate analysis banana flour that have the genomes (ABB)

Table 4.2 Result of Proximate Analysis on Banana Starch (ABB)

Parameter	Unit	Type of Banana (ABB) from Musa spp		
		Kepok	Monthan	Karpuravalli
Moisture content	%	15.72	8.40	8.30
Ash	%	0.47	2.54	1.20
Fat	%	0.00	0.75	2.06
Protein	%	0.17	1.45	3.25
Carbohydrate	%	83.65	85.76	83.79

From the table above, it is shown that Starch from Kepok have the highest moisture content due to the other. This may relate to the storage condition . In addition, not optimal drying process of the starch and repeated cycle of extraction my process using NaOH and water may become additional factors that increase the moisture content.

From the ash parameter, Kepok starch tend to have the least value, this mean less residue are present from the starch. In term of fat, Kepok have no fat content at all where compare to the other two. This may be cause from the method of analysis. Insensitive method of analyzes may cause the fat content to be read as zero although there is possibilities that the fat content is not 0.0 but few number behind comma.

Protein content of Kepok decrease due to the interaction with NaOH during the extraction process , where NaOH breaks the protein resulting in having the least amount of protein among the starches. Lastly, in terms of Carbohydrate, all starches tend to have high carbohydrates value which lays in the range of 83.65% – 85.67%. With having high carbohydrate content, Starch from kepok banana made through water alkaline based extraction could be further processed for modification and source of high carbohydrate food.

4.3 Modification of RS2 to RS 3

Banana starch that mostly compose of RS2 is modified with two methods in order to achieve RS 3 which known to be more stable in terms of heat and other physical treatment. The modification were done with two methods. The first method consists of combining debranching and two cycles of autoclaving cooling where the second method consist of three cycles of autoclaving cooling. In this study, methods of modification are observed and discussed.

Banana starch which compose of RS 2 should be modified in to achieved RS 3 which have a better thermal stability compare to RS 2. (Sanz, 2008). Furthermore, with the modification of RS2 to RS 3, it will increase the resistant starch value where it can be seen by the approach of starch digestibility and amylose content. With having a relative better thermal stability, mechanism of resistant starch after frying with high heat could still work.

Comparing the process of autoclaving cooling with 3 repetition and combine methods of debranching and autoclaving methods, repeated cycle of autoclaving cooling is more time effective and less costly.

4.4 Starch Digestibility and Amylose Content

Starch digestibility correlates well with rate of starch digestion where it shows the ability of the starch to be digest. Starch can be classified into 3 big groups which consist of rapidy digestible, slowly digestible and resistant starch (Englyst, 1999). Starch digestion is influenced by the composition itself where factors such as RS content ,dietary fiber and amylose content plays role in determining the starch digestibility.

Starch digestibility and amylose are analysed since it is 2 parameters that correlate to RS content and one of the approached in determining RS Content.

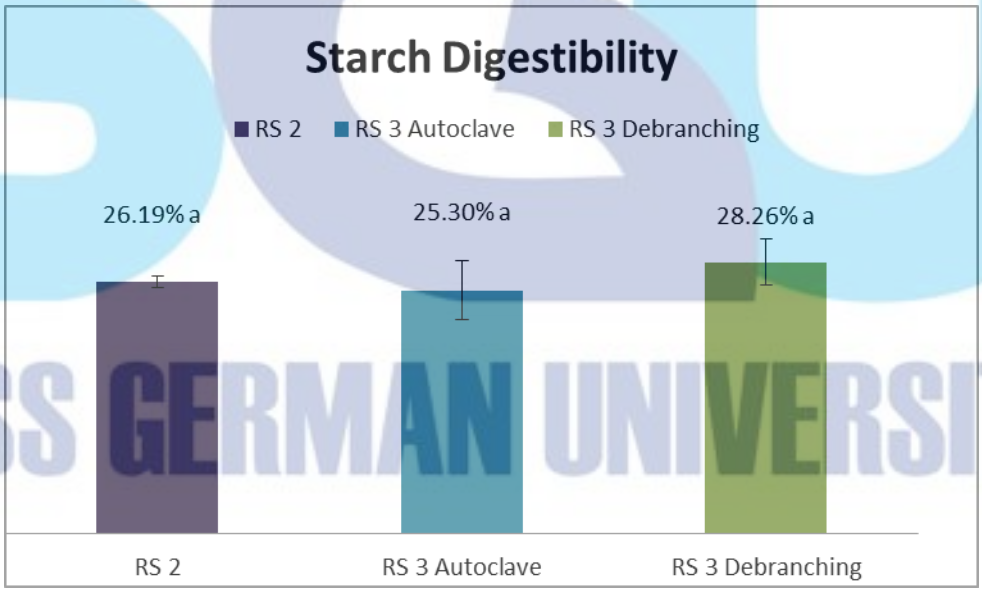

Figure 4.1 Result of Starch Digestibility in Starch

In this study, banana starch were used where the value of the starch digestibility through in vitro methods were in the value of 25 % - 28% where it is already in the range of digestibility which is around 49 % present in figure 4.2

DIGESTIBILITY OF UNCOOKED STARCHES

Starch	In Vitro Hydrolysis (%)	In Vivo Apparent Digestibility (%)
Cereal[11,43,53,54,59,60,66,92]		
Maize	70—100	98—100
High Amylose Maize	15—45	66—77
Waxy Maize	90—100	98
Oat	75	—
Rice	18—100	98—100
Rye	75	97—99
Sorghum	56	—
Waxy Sorghum	80	—
Wheat	70—100	98—100
Root/Tubers[28,44,45,53,54,71]		
Arrowroot	20	80—96
Canna	4	53
Cassava	55	95—97
Potato	3—10	27—78
Taro (*Colocasia antiquorum*)	100	99
Fruit[a]		
Banana	11—31	49
Legumes[40,47,50,52]		
Phaseolus sp.	20—91	90—100[a]
Vigna sp. (Mung bean)	40—67	100[a]

[a] Spray dried with outlet temperature of 90°C.

Figure 4.2 Digestibility of uncooked starches (Dreher et al., 2009)

Compared the mean value of 49% present at Figure 4.2, it shows that banana starch from unripe Kepok banana shows lower starch digestion which indicate good result of digestibility value and successful modification process.

Banana starch is considered to have small digestibility value since banana is classified into least digestible where with being least digestible, it have high degree of crystalinity and result in slower penetration of α- amylase during the in vitro process. With the low penetration, it will result in slower digestibility.

Referred to Figure 4.1 it shows that RS 3 Autoclave have the lowest starch digestibility value followed by RS 2 and RS 3 Debranching. With lower digestibility value this means, there is smaller portion of digestible starch component compare to the indigestible one or also known as Resistant Starch (RS). This correlates that, RS 3 Autoclave have the highest amount of RS compare to the other 2 since it have the smallest value of starch digestibility which means there are smaller portion of the starch that is digestible and could be digested by α – amylase enzyme. This shows that

modification process have successfully increased the RS value concluded from the starch digestibility approach.

Correlating Starch digestibility with the amylose content, since it have negative correlation, with the increasing value of amylose content it should be followed with declining of starch digestibility. Since RS 3 debranching shows the highest amylose value, it should have the least starch digestibility but according to the data it shows the opposite.

Its is found that RS 3 debranching have higher digestibility value compare to RS 3 autoclave. Yet this could be explained referring to previous study made by Guraya et al., 2001 where he observed the effect of debranched rice towards the digestibility. In his study, methods use were similar which consist of using Pullulanase enzyme and process including freezing and drying. In his study, it was found that debranching method, it actually increased the portion of Rapidly Digestible Starch and decrease in Resistant Starch. It is found that process of debranching that uses freezing, milling and drying actually reduce and broke down crystalline structured form during cooling which result in increasing value of digestible starch.

In addition, increase of starch digestibility in debranching is due to the nature of the starch made by debranching. There are two main factors that correlates towards the ineffective debranching. The first indication is the non – optimal concentration of the pullulanase enzyme. When the concentration of enzyme is not optimum, produce of short chain amylose is not optimal, resulting in a very short chain amylose .With the presence of very short chain it will not be retrodegraded in result it will increase the starch digestibility.

With the explanation it could then be seen why RS3 debranching have higher starch digestibility value although having the highest amylose content.

Starch are made out of 2 major component where one of them is amylose. Amylose is the linear portion is composed of several hundreds or thousands of glucose units linked by 1,4-alpha-glucopyranosidic bonds (Dreher et al., 2009). Amylose are analyzed since it correlated well with starch digestibility and RS content.

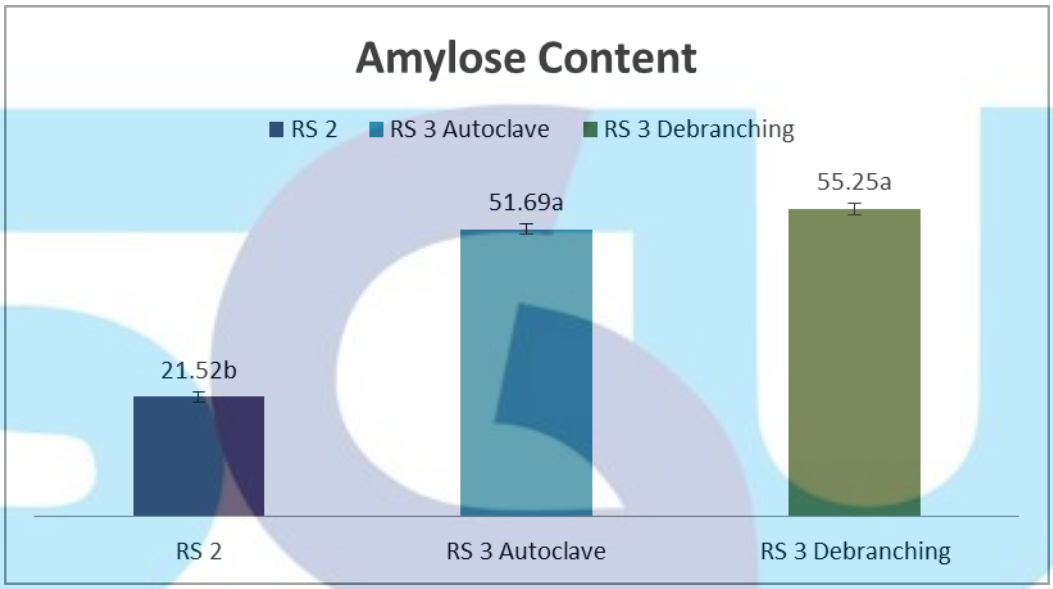

Figure 4.3 Amylose content of starch

As seen in figure 4.3 , Amylose content present in RS 2 have the value of 21.52% where actually the value tends to be smaller compare to the number of amylose content present in ABB type banana studied by Vatanuschart having the range of amylose content from 39.3% to 43.8%

However, through modification of Resistant Starch type 2 both using autoclaving and debranching method increase the amylose content. It is statistically shown that there is different among the starches and RS 3 debranching have the highest value of amylose content up to 55.25%.

Amylose content plays factor toward the starch properties such as water retention capacity, fat content and starch digestibility. In terms of starch digestibility, amylose content have negative correlation with starch digestibility and positive correlation

with RS content (Dreher et al., 2009 and Mir et al., 2012). This means with the increasing value of the amylose content, it will be followed with the decreased of starch digestibility yet increase of RS content. The correlation could be expressed as :

This correlation is also supported by Sheresta et al., 2012, it is found high amylose starch granules do not have extensive pores. This then make enzyme digestion to proceed from the outside where outside layer molecularly is more organized and have effective barrier for enzyme to digest the less organized interior.

Higher amylose content is also a good indication of the RS content since amylose retrodegrades in faster rate compare to amylopectin. By then amylose are usually used as reference to see the tendency of starch retrodegration. With the increase of amylose content, it will increase the tendency retrodegration hence higher RS content.

Comparing the data and the theory, it is shown that the modification process of RS towards RS 3 succeed since it result in higher amylose content. Observing from the amylose value, RS 3 debranching supposed to be having the highest amylose content which result in lowest starch digestibility yet higher RS content.

4.5 Analysis of Product

4.5.1 Physical Evaluation of RS2 & RS 3

Physical properties of the starch and after being applied into batter and product are observed visually by looking on the starch appearance and texture . Result are present in table 4.3 and will be explained in the following subchapter.

4.5.1.1 Properties of Starch

Table 4.3 Properties of starch

Picture	Type of Starch	Description
	Control - Wheat Flour	Wheat flour is used as the control
	Resistant Starch 2	It is the most white and pure in terms of color. It has smooth powdery texture and odorless. Most similar to control among the others
	Resistant Starch 3 – Autoclave	In color it is not as white as RS 2, it have a more course texture like creamer. It is odorless and to be more grainy in texture.
	Resistant Starch 3 – Debraching	White in color and have big grainy texture like crystal sugar. In texture it is more coarse and hard. Have strong sour / acidic.

Evaluation of the starch used as the raw material were characterized. Referring to table 4.5.1.2.1 , RS 2 and RS 3 have different physical characteristic from one to the other. In color, RS 2 is more white compare to the other type of resistant starch. Factors that differentiate between starch is from the aroma and texture.

In term of texture, RS 2 have smooth and soft texture. Meanwhile, RS 3 have a more coarse and gritty texture both in autoclaving and debranching, though they are able to be differentiate from the different intensity of coarseness. RS 3 debranching is more intense and tend to be more like crystal sugar where in the other hand RS3 Autoclaving have a creamer like texture. In terms of Aroma, Resistant starch 3 Debranchinng have a strong acidic aroma due to the acetic acid used in the modification of the starch. The result actually differs from the characterization made by Nugent, 2015, where resistant starch are supposed to be odourless, colourless and tasteless.

4.5.1.2 Properties of Batter

Starch that have been put through formulation and added with constant amount of water are observed as batter coating before applied to product. Result are present in Table 4.4.

Table 4.4 Table physical properties of batter

Picture	Type	Ratio of Resistant Starch	Description
	Control	0%	Consistency of the batter coating is well, broken white in color. Act as the reference
	RS 2	10%	More viscous compare to control. There is no different in color. Texture of the batter is smooth and not grainy
	RS 2	30%	Less viscous compare to batter with addition of 10% RS. There is no different in color . Texture of the batter is smooth and not grainy
	RS 2	50%	Least viscous compare to the other 2 ratio. There is no different in color. Texture of the batter is smooth and not grainy

	RS 3 Autoclave	10%	Tend to be more opaque compared to control in color. In terms of viscosity, the viscosity is more viscous compare to control.
	RS 3 Autoclave	30%	Tend to be more opaque compared to control in color. The batter is more viscous compare to ratio 10%. The batter have a thick consistency.
	RS 3 Autoclave	50%	Tend to be more opaque compared to control in color. It is most viscous compare among the ratio. The texture is sticky and thick and tend to be more like cookie/ bread dough
	RS 3 Debranching	10%	The batter is more viscous compare to control. The batter have a gritty texture. Coarse particle and gritty hard texture like particle can be seen in the batter. Have a slight aroma of acetic acid
	RS 3 Debranching	30%	The batter is more viscous compare to batter with addition of 10% RS. Coarse particle and gritty hard texture particle can be seen in the batter. The aroma of acetic acid is more intense compare to addition of 10% RS .
	RS 3 Debranching	50%	The batter have the highest viscosity among the 3 ratio. Gritty coarse particle are most visual in this ratio. Intense acetic acid aroma.

Evaluating the data, in terms of color there is no difference that is significant that can be seen visually but difference in between samples can be seen through the aroma, consistency of product and texture of the batter.

In term of aroma, batter that contain RS 3 debranching have an acidic smell, the higher the ratio substitution of RS, the more intense the smell of acetic acid. In term of texture, debranching also shows gritty texture compare to the other resistant starch and control. In the batter, coarse particle can be seen and not homogenous like control. Observing the consistency of the product, it shows that different type of RS used at different ratio shows different consistency.

At RS2 , the higher the substitution ratio, the viscosity of the batter tends to decrease. At ratio level of 50%, batter tend to be slurry and have low viscosity. In contrary, RS 3 shows the direct opposite result. Higher substitution level of resistant starch result in higher viscosity of batter. Seen at RS 3 autoclave, at the highest ratio of 50%, the dough have high viscosity that it tends to be more like cookie dough instead of batter coating.

Correlation of increasing RS 3 ratio towards the increase viscosity is due to the ability of starch especially modified starch to be used as thickeners. According to Abbas et al., 2010,starch are modified since modified starch have special properties such a gelling and thickener properties. RS 3 both from autoclaving and debranchng is modified starch , consisting of retrograded amylose that is formed by physical modification which consist of pregelatinization & heat treatment. Furthermore, Abbas et al., 2010 mentioned that pre gelatinized starch can be used as precooked starch which act as thickeners in cold water. With its ability to work as thickening agent it will have the mechanism of involving non specific entanglement of conformationality disordered polymer chain.

Since RS 3 work as thickening agent even at cold water, it explain the directly proportional correlation between ratio of RS content towards the viscosity. Observing from the trend given by RS 2, which correlate negatively between ratio of RS and the

viscosity, is due to the polymer dispersion . Starch in native and modified form is the most common hydrocolloid thickener (Babic et al., 2009), thickening happened at above critical concentration known as the overlap concentration C *, below this level polymer dispersion exhibit Newtonian behavior but shows a Non – Newtonian behavior.(Saha and Bhattacharya, 2010). With the condition, there is possibility that RS2 is below the critical concentration so although it acts as a thickening agent but it correlates negatively since it is still below the critical level resulting the Non – Newtonian behavior.

Batter should actually have the right consistency, since too low viscosity batter will release high amount of water and produce porous coating which absorb more oil. In contrary, batter that is too thick is also not preferred since it may cause the product to uncooked and decrease the crispiness attribute where crispiness is one the of the major attribute in fried products.

4.5.1.3 Properties of Batter applied to product

Addition of resistant starch to the battered product showed visual difference but will be more discussed through the sensory evaluation and analysis of the product. Through the physical appearance, addition of RS increase the physical appearance by enhancing the color.

From the result present in table 4.5., Tempeh coated with batter containing RS 2 and RS 3 is different by visual. Substitution of RS 3 creates a better visual appearance on the product crust with providing golden brown crust and thicker coating around the Tempeh. Effect of battered product correlates well with batter texture and consistency..

Observing from the substitution ratio, it can be seen that both RS 2 and RS 3 at substitution ratio of 50% have low coating ability . This is visualized throughout the product where parts of tempeh can still be seen clearly and result on uneven coating towards the Tempeh.

From the properties of batter applied to product, it shows that RS3 shows better result visually compare to RS 2. Furthermore, ratio of 50% is not recommended to be used due to the less accepted result of the product.

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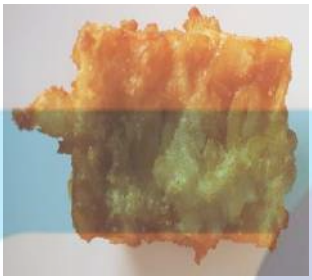
Table 4.5 Physical properties of battered product

Picture	Type	Ratio of Resistant Starch	Description
	Control	0%	Set as the reference
	RS 2	10%	Color is less bold than control. Coat the product best compare to the other 2 ratio
	RS 2	30%	Color is less bold than control. Coat the product better compare to RS 2 at 50%
	RS 2	50%	Color is less bold than control. Low coating ability. Uneven coating of the product.
	RS 3 Autoclave	10%	Color is more bold and golden brown compare to control and RS 2. Product is coated well, all parts are covered.

	RS 3 Autoclave	30%	Color is more bold and golden brown compare to control and RS 2. Have the best coating property. Create a thick and even coating around the product.
	RS 3 Autoclave	50%	More golden brown in color compare to control. Create thick uneven coating around the product. Parts of the product can be seen. Have the worst coating abbility among the 3 sample.
	RS 3 Debranching	10%	More golden brown in color compare to control. Create even coating around the product.
	RS 3 Debranching	30%	More golden brown in color compare to control, create even and thicker coating compare to addition of RS 10%
	RS 3 Debranching	50%	More golden brown in color compare to control, create uneven coating around the product. Parts of the product can still be seen.

4.5.2 Effect of Resistant Starch on the batter and battered product properties

Table 4.6 Effect of Resistant Starch 2 towards the batter and battered product properties

Type	Ratio (%)	Coating Pick Up (%)	Water Retention Capacity (%)	Fat Content (%)
Control	-	37.58 ± 5.42 [a]	58.58 ± 0.02 [a]	19.69 ± 0.08 [b]
RS 2	10	36.70 ± 3.09 [a]	56.23 ± 0.75 [b]	17.01 ± 0.06 [c]
	30	34.58 ± 4.43 [a]	55.23 ± 0.25 [b]	16.79 ± 0.06 [c]
	50	22.34 ± 1.44 [b]	54.03 ± 0.12 [c]	24.89 ± 0.12 [a]

Table 4.7 Effect of Resistant Starch 3 – Autoclave towards the batter and battered product properties

Type	Ratio (%)	Coating Pick Up (%)	Water Retention Capacity(%)	Fat Content (%)
Control	-	37.58 ± 5.42 [b]	58.58 ± 0.02 [d]	19.69 ± 0.08 [a]
RS 3 Autoclave	10	52.02 ± 4.46 [a]	61.49 ± 0.30 [c]	12.58 ± 0.08 [b]
	30	54.01 ± 5.02 [a]	74.04 ± 0.18 [b]	10.91 ± 0.08 [c]
	50	52.44 ± 2.70 [a]	100.00 ± 0.00 [a]	12.81 ± 0.08 [b]

Table 4.8 Effect of Resistant Starch 3 – Debranching towards the batter and battered product properties

Type	Ratio (%)	Coating Pick Up (%)	Water Retention Capacity(%)	Fat Content (%)
Control	-	37.58 ± 5.42 [a]	58.58 ± 0.02 [d]	19.69 ± 0.08 [a]
RS 3 Debranching	10	43.39 ± 3.07 [a]	79.33 ± 0.51 [a]	10.32 ± 0.08 [d]
	30	43.98 ± 1.34 [a]	65.10 ± 0.21 [c]	17.83 ± 0.08 [b]
	50	45.67 ± 5.63 [a]	73.09 ± 0.30 [b]	12.88 ± 0.08 [c]

The table show differences among sample. Different code in same columns indicate the differences among sample analyze through ANOVA at $\alpha = 0.05$ and continue with Tukey HSD when significant different is present. Each analysis and the effect of RS towards the result will be discuss in the following subchapter.

4.5.2.1 Fat content

Previous study have mentioned that Resistant Starch have the ability to reduce oil absorption once applied in the product. In this study, application of Resistant Starch from unripe " Kepok" banana will be observed to see its effect in reducing the fat content.

Table 4.9 Effect of Resistant Starch towards Fat Content of battered product

Ratio (%)	RS 2	RS 3 Autoclave	RS 3 Debranching
Control	19.69 ± 0.08 [b]	19.69 ± 0.08 [a]	19.69 ± 0.08 [a]
10	17.01 ± 0.06 [c]	12.58 ± 0.08 [b]	10.32 ± 0.08 [d]
30	16.79 ± 0.06 [c]	10.91 ± 0.08 [c]	17.83 ± 0.08 [b]
50	24.89 ± 0.12 [a]	12.81 ± 0.08 [b]	12.88 ± 0.08 [c]

From the result present at Table 4.9 , it is proven that with the addition of RS, it reduce the oil absorption both in RS 2 and RS 3. However, the decrease in fat content made by RS 2 is not as much as it is in RS 3. It is seen in the first substitution ratio that with the addition of RS2 , fat content only decrease 2.68% meanwhile RS 3 could decrease the fat content up to 7.11% from RS 3 Autoclave and 9.37% in RS 3 debranching. Furthermore, RS 2 show unstable trend where at the highest level of substitution, it increase the fat content more than control instead of reducing it. Due to this reason, RS 2 will be no longer discuss and proven that RS 3 is better in reducing oil absorption compare to RS 2.

Comparing the result between 2 type of RS3, although initially at 10% RS 3 debranching could reduce oil absorption better than RS 3 Autoclave, it will no longer

be elaborated since the due to the instable trend given. According to the theory, the increase in ratio of RS should be followed by the decrease of fat content, however RS 3 debranching reacts in the opposite. RS 3 Autoclave however shows a more stable trend , although at 50% ratio, there is an increase in oil absorption it could be neglected since 50% ratio of RS 3 Autoclave is not considered and preferred due to the over viscosity of the batter. Since the viscosity of the batter is to high, its coating ability reduce which may become 1 factor that increase the oil absorption.

Referring to table 4.9,RS 3 Autoclave works best at ratio 30% with reducing fat content up to 10.91%. As stated earlier, factors such as Water Retention Capacity and Oil pick Up are of the crucial factors that plays role in reducing fat absorption. As seen in table 4.7, that shows the correlation of the 3 factors, it is shown that at the ratio of 30% least oil absorption are followed by the highest value of coating pick up and water retention capacity. Since it have high coating pick up, the batter creates good coating around the product, making less media transfer of oil and water during frying. It is also strengthen with the high water retention capacity where with high water retention capacity, it have film forming ability making penetration of the fat into the product to weakens.

As result, RS 3 autoclave at ratio 30% substitutions shows the best result in term of reducing oil absorption.

4.5.2.2 Water Retention Capacity

Through water retention capacity (WRC), ability of the batter to hold the water can be observed. WRC itself contributes to the fat content that will be present in the product since WRC and fat content have an inversely proportional correlation. The increase in the WRC value will decrease the fat content. Previous studies made by Sanz et al., (2007) and Moradi et al., (2013) have proven shown that with the addition of Resistant Starch, it will increase the WRC and resulting in the decreased of fat content.

Sanz et al., (2007) correlates that with the addition of RS 3 in the batter coating it reinforce the moisture content barriers against fat and moisture loss during frying with result of the decrease in fat content and increase in moisture content. Correlation are also found that with the addition of RS3, fat content could decrease due to the thermogelling and filmforming properties of the RS 3, where filmforming correlates with the amylose content (Shih and Daigle , 1999).

According to Shih and Daigle.1999, amylose have the ability of good filming properties. With the good filming properties, it will enhance the water retention capacity and provide a more affective oil barrier during frying which result in lowering the fat content.

Table 4.10 Effect of RS to Water Retention Capacity of Batter

Ratio (%)	RS 2	RS 3 Autoclave	RS 3 Debranching
Control	58.58 ± 0.02 [a]	58.58 ± 0.02 [d]	58.58 ± 0.02 [d]
10	56.23 ± 0.75 [b]	61.49 ± 0.30 [c]	79.33 ± 0.51[a]
30	55.23 ± 0.25 [b]	74.04 ± 0.18 [b]	65.10 ± 0.21[c]
50	54.03 ± 0.12 [c]	100.00 ± 0.00 [a]	73.09 ± 0.30 [b]

Based on the result present at table 4.10 shows that the addition of RS 3 increase the value of the WRC. Comparing RS 2 and RS 3, it is shown that RS 3 have better properties in increasing the WRC value where with the addition of RS3 there is an increase in value compare to control. In contrary, RS 2 decrease the value of WRC.

Comparing both RS 3 that is modified from 2 methods, RS 3 achieved by combine method of debranching - autoclaving cooling show better result at ratio of 10% compare to autoclaving – cooling. This can correlates to the amylose content of the raw starch present in figure 4.4.1 that shows RS 3 Debrancnhing have the highest value of amylose content, where high amylose leads to better film forming thus enhancing the water retention capacity (Shih and Daigle, 1999).

However, although both increase the WRC value and initially at ratio of 10% RS 3 debranching shows higher value, it is found that RS 3 Autoclave have a more stable trend by showing positive correlation between increasing level of RS substitution towards the WRC value, by then RS 3 Autoclave is chosen and will be more elaborated.

Comparing the effect of different ratio of substitution towards the WRC in RS 3 autoclave it shows that increase in ratio is also followed by the increase in WRC. Furthermore , the WRC value present at 50% RS 3 Autoclave have even reached double the control and reached a perfect value. This value can be correlated to the texture of the initial batter coating before centrifugation where it tends to be very viscous and have the texture and appearance of more of a cookie dough compare to a batter coating. Due to this reason, although the value of at 50% ratio reach WRC value of 100%, it is not preferred due to the characteristic of the dough that don't have the right consistency to be batter coating and in contrary it is more suitable to become cookie dough since of its high viscosity and less suitable for batter coating. Yet it can be stated that RS 3 Autoclave at 30% substitution ratio have the best effect towards the water retention capacity of batter.

4.5.2.3 Coating Pick Up

As stated by Suderman (1983), coating pick up shows the amount of batter adhering to the tempe during battering. Sanz et al, 2007 also state that coating pick up is an important evaluation since it is directly to the product yield.

In previous study made by Sanz et al., 2007 Sanz shows that coating pick up relate to the batter consistency. High viscosity batter result in batter pick up and less viscous batter or easily flowing batter shows less coating pick up due to less covering power to the food substrate. In his study, he also saw that RS 3 (Novelose 330) shows a better result compared to RS2.

Table 4.11 Effect of Resistant Starch towards coating pick up of battered product

Ratio (%)	RS 2	RS 3 Autoclave	RS 3 Debranching
Control	37.58 ± 5.42 [a]	37.58 ± 5.42 [b]	37.58 ± 5.42 [a]
10	36.70 ± 3.09 [a]	52.02 ± 4.46 [a]	43.39 ± 3.07 [a]
30	34.58 ± 4.43 [a]	54.01 ± 5.02 [a]	43.98 ± 1.34 [a]
50	22.34 ± 1.44 [b]	52.44 ± 2.70 [a]	45.67 ± 5.63 [a]

Comparing the data in table 4.11, addition of RS increase the ability of the batter to coat the food product seen in the increasing value of coating pick up compare to control. However, this term only apply in RS type 3 since RS 2 shows the direct opposite by the decreasing value compare to control. This then correlates to previous study that RS 3 shows higher coating pick up value compare to control and RS2.

Although both RS 3 improve the coating pick up ability, RS 3 autoclave will be more discussed since increase caused by RS 3 debranching is shown not to be statistically significant compare to control. Furthermore, the value of increase is still smaller compare to RS 3 autoclave. Referring to Sanz et al., 2007 , batter containing RS 3 autoclaving tend to be more viscous compare to control and the other RS type. The higher the ratio of the RS, The viscous the batter become. At the ratio of 50%.it tend to be so viscous that the batter don't become runny at all. Due to the consistency of the batter, this relates that RS 3 autoclaving shows the best covering power to the food substrate in this case tempe.

Since RS 3 Autoclave in terms of RS type shows the best result, seen in different additional ratio, ratio of 30% ratio of RS shows it peak at the value of 54.01% coating pick up. Although supposed to be at 50% shows the highest result, but since at 50%, the batter consistency have become to thick in order to call it a batter coating it result in decreased value of coating pick up compare to 30%. At 10%, the batter have less consistency and more runny compare to the other ratio. Due to the

inconsistency, it shows smaller covering power. As a result, RS 3 Autoclave at 30% ratio shows the best result in coating pick up.

4.5.3 Effect of RS on the battered product sensory properties

Based on the physical appearance and the result of the chemical analysis, elimination were done to select selected type of resistant starch and ratio to be further analyze through sensory evaluation. In this case debranching and ratio of 50% are eliminated and are not evaluated through sensory evaluation.

Debranching is totally removed from measurement because in term of modification process, debranching is more costly and less time efficient. From the properties of th starch, RS 3 debranching have a strong acidic aroma which still can be recongnized in the batter which is not homogenous since gritty coarse particle are visual in the batter. Futhermore RS 3 debraching is removed since through analysis of product (fat content, WRC and coating pick up) it shows unstable trend and is not as effective as RS3 autoclave in reducing oil absorption.

Level of substitution 50% is removed from the measurement since at substitution ratio of 50%, the batter have a very high viscosity and does not show good coating ability to the product. Furthermore, through analysis of product, at ratio 50% it don't decrease the oil absorption but shows the opposite result.

Due to supporting factors to remove debranching and level of substitution 50% , RS2 and RS 3 at the substitution level 10% and 30% were further examined through sensory evaluation.

In the sensory evaluation done through hedonic scoring, where panelist are asked to score the sample from a scale out of 9. Where 9 is like extremely and 1 is dislike extremely.The result were analyzed using Friedman's test and if there is significant different, the result will be further analyzed using Wilcoxon's test. The result are present in Table 4.12

Table 4.12 Result of Sensory

Type of Batter	Appearance	Color	Crispiness	Oiliness	Flavor	Overall Acceptability
Control	6.57 ± 1.88[a]	6.97 ± 1.65[a]	5.74 ± 1.93[c]	6.03 ± 1.52[b]	6.66 ± 1.49[ab]	6.57 ± 1.27[c]
RS 2 10%	6.51 ± 1.67[a]	6.51 ± 1.77[a]	4.94 ± 1.47[c]	5.20 ± 1.55[c]	6.71 ± 1.34[a]	6.23 ± 1.48[cd]
RS 2 30%	6.89 ± 1.41[a]	7.09 ± 1.56[a]	6.49 ± 1.79[b]	6.46 ± 1.52[b]	7.37 ± 1.06[a]	7.00 ± 1.35[c]
RS 3 Autoclave 10%	7.20 ± 1.43[a]	7.31 ± 1.28[a]	6.40 ± 1.96[ab]	6.09 ± 1.85[b]	6.83 ± 1.96[a]	7.43 ± 1.07[b]
RS 3 Autoclave 30%	6.74 ± 1.79[a]	6.80 ± 1.71[a]	7.37 ± 1.42[a]	7.14 ± 1.12[a]	7.14 ± 1.84[a]	7.51 ± 0.82[a]

The table show differences among sample. Different code in same columns indicate the differences among sample.

4.5.3.1 Appearance

Based on the sensory result , it is shown that addition of RS increase the appearance value although statistically there is no significant difference between samples. In terms of mean value, addition of 10% RS 3 Autoclave shows the highest value

4.5.3.2 Color

Addition of RS does not have a big impact in the color of the product, this can be seen since statistically there is no significance difference in between sample. In term of mean value, addition of 10% RS 3 Autoclave shows the highest value.

4.5.3.3 Crispiness

Addition of RS effect the crispiness attributes, however 10% RS 2 shows inversely proportional result. Shown that with addition of RS 2 10% decrease the crispiness compare to control. Statistic shows that there are significance different and correspondent prefer crispiness resulting from addition of 30% RS 3 Autoclave. This relates to previous study that addition of RS increase the sensory properties such as crispiness. Although at 30% level substitution of RS 3 Autoclave shows high water retention capacity which correlates to the increase of moisture content, it does not affect the crispiness attributes and shows that it is significantly preffered by the panelist.

4.5.3.4 Oiliness

Addition of RS effect the oiliness attributes of the product. There are significant different among the product. It is seen that correspondent prefer oiliness of the product with addition of 30% RS 3 Autoclave where the oiliness is the most preferred among the other sample including control. This is consistent with the result of fat content analysis that at ratio 30% RS 3 Autoclave provide less oil absorption and through sensory it is preferred as the least oily.

4.5.3.5 Flavor

Addition of RS does not contribute into the flavor attribute since there is no significant difference between the product.

4.5.3.6 Overall Acceptability

It is shown that 30% RS 3 autoclave in the product have the highest score for the overall acceptability and proven statistically that there are difference between the samples .Although in terms of color and appearance , 30% RS 3 Autoclave does not have the highest mean value but among the other attributes, it stands out resulting in the most preferred and acceptable starch and ratio substitution.,

Overall , addition of Resistant Starch generally increase the acceptability of product compare to control. Seen that from table 4.12, RS 3 autoclave 30% have significantly increase the acceptability and the acceptance. RS 3 prove to increase crispiness, reduce oiliness, enhance flavor and increase the overall acceptability of the product.