PREPARATION OF MODIFIED STARCH FROM SWEET POTATO AND ITS APPLICATION IN SOME FOOD PRODUCTS

Khin Hla Mon[1], Sandi Bo Bo[2]

Abstract

Starch is a carbohydrate consisting of a large number of glucose units joined by glycosidic bonds. It can be modified chemically to increase their positive attribute. The present research work was focused on the preparation of modified starch from sweet potato using both acid treatment method and cross-link method. The prepared modified starch was used in the preparation of some food products such as biscuit and mayonnaise. Fresh and mature sweet potatoes were collected from Pyin Oo Lwin Township, Mandalay Region. The most suitable conditions for the preparation of starch were 1:6 (w/v) ratio of sweet potato to water at 4 hr settling time. The most favourable conditions for the preparation of modified starch from sweet potato by acid treatment were 0.5 mL of 10 % hydrochloric acid at room temperature for 15 min. In cross-link method, the most suitable conditions were 5mL of 0.1 % sodium tripolyphosphate at room temperature for 30 min. The characteristics of starch and modified starches such as ash, moisture, pH, gelatinization temperature, solubility, swelling power and amylose content were investigated. Both sweet potato starch and prepared modified starches by two different methods were identified by FT-IR and SEM method. It was used in the preparation of mayonnaise and biscuit.

***Key words*:** glycosidic bonds, cross-link method, gelatinization

Introduction

Sweet potato (*Ipomoea batatas* L.) is a tuberous rooted perennial plant belonging to the convolvulaceae or morning glory family and the main commercial producers of sweet potatoes are China, Indonesia, Vietnam, Japan, India, Myanmar and Uganda. The main utilization of sweet potato is in the starch manufacture and has many applications due to its starch composition. The quality of sweet potato tubers flour and starches appear not only to be affected by the content of the starch in the tuber, but also the amylose- amylopectin ratio of the starch and the chemical composition of the

[1] Professor and Head, Department of Industrial Chemistry, Dagon University.
[2] MSc Student, Department of Industrial Chemistry, Dagon University.

tuber (Hoover, 1985; Moorthy, 2002). In Myanmar, sweet potatoes are farmed in Sagaing Region, Mandalay Region, Ayeyarwaddy Region, Yangon Region, Bago Region and other tropical places. Starches have limitations which reduce their use at industrial level due to the inability tolerate a wide range of processing techniques, distribution and storage conditions. Modified starches are superior to starches due to their improved functional properties and are widely employed in processed food in several years. It is used in pharmaceuticals, biodegradable polymers and as food additives. Starch is a carbohydrate consisting of a large number of glucose units joined by glycosidic bonds. Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 and 80% amylopectin by weight. Amylose is also an important thickener, water binder, emulsion stabilizer and gelling agent in both industrial and food based contexts. Amylopectin is a soluble polysaccharide and highly branched polymer of glucose found in plants. (http://www.wikipedia.org.com)

The present research investigated the preparation of modified starch from sweet potato using two different methods: acid treatment method and cross-linked method. This modified starch was identified by FT-IR method, followed by the determination of amylose and amylopectin content.

Materials and Methodology

Materials

Fresh and mature sweet potatoes were collected from Pyin Oo Lwin Township, Mandalay Region. All the chemicals used were India made, Analar grade hydrochloric acid, sodium hydroxide, sodium tripolyphosphate.

Methodology

Preparation of Sweet Potato Starch

Fresh sweet potatoes were thoroughly washed with tap water to remove the impurities such as dirt, grit and dust. Then, raw sweet potatoes were peeled and washed with tap water. 100g of sweet potatoes were crushed

in a blender. The resultant paste was soaked in water in the ratio of 1:6 (w/v%) for 60 min at 30ºC by stirring with a constant rate of 150 rpm. The sweet potato starch slurry was filtered through a nylon cloth to obtain the starch granules. The starch granules in the filtrate were settled for 4 hr, and then water was decanted to separate out the starch. The starch granules were washed with tap water two times. The starch was sun-dried and pulverized using mortar and pestle to obtain a fine powder. The prepared sweet potato starch is shown in Figure (2). Effect of sweet potato to water ratio (1:3,1:4,1:5,1:6,1:7 and 1:8) and effect of settling time (1,2,3,4,5) hr on the yield of sweet potato starch were investigated using the same procedure mentioned above.

Figure 1: Sweet Potato

Figure 2: Sweet Potato Starch

Preparation of Modified Starch from Sweet Potato by Acid Treatment Method

Dried sweet potato starch 5g was thoroughly mixed with 0.5 mL of 20% hydrochloric acid in a 250 mL beaker and stirred for 15 min at 40ºC. The slurry was completely neutralized with 1 mL of 0.01 % sodium hydroxide. The slurry was washed with water and settled for one day. After that, it was separated by decantation of water. The starch was sun-dried for 90 min and pulverized using mortar and pestle to obtain fine powder. The prepared modified sweet potato starch by acid treatment is shown in Figure 3(a). Effect of volume of 20% hydrochloric acid (0.25,0.5,1.0,1.5,2.0,2.5) ml, effect of concentration of 0.5ml of HCL (5,10,20,30,40,50) % and effect of reaction temperature (30,40,50,60)°C on the yield of sweet potato modified starch were determined using the same procedure as mentioned above.

Preparation of Modified Starch from Sweet Potato by Cross-link Method

Dried sweet potato starch 5g was mixed with 10 mL of water for 10 min. 5 mL of 0.1% sodium tripolyphosphate and 5 mL of 0.1% sodium hydroxide were added into the starch slurry and stirred in a small scale batch type mixer for 30 min at 30ºC. The pH of the slurry obtained was adjusted to 6-7 using 0.3% hydrochloric acid. The slurry was washed two times with tap water and settled for one day. Then, water was decanted to separate out the starch. The starch was sun-dried for 90 min and pulverized using mortar and pestle to obtain a fine powder. The prepared sweet potato modified starch by cross-linked method is shown in Figure 3(b). Effect of volume of 0.1% sodium tripolyphosphate (1,3,5,7,9) ml, effect of concentration of 5 ml sodium tripolyphosphate (0.05,0.10,0.15,0.20 and 0.25) and effect of reaction temperature (30,40,50, 60,70) ºC on the yield of sweet potato modified starch were investigated the same procedure as mentioned above.

(a) Acid Treatment Method **(b)** Cross-linked Method

Figure 3: Modified Starch

Determination of the Characteristics of Starch and Modified Starch

The characteristic of starch and modified starch such as ash, gelatinization temperature, moisture, pH, solubility, swelling power, amylose and amylopectin content were determined.

Results and Discussion

Figure (4) shows the results of the effect of ratio of sweet potato to water on the yield percent of sweet potato starch. Although the ratio of sweet potato to water was increased to 1:7 (w/v) and 1:8 (w/v), the yield percent of

sweet potato starch does not apparently increased. So, 1:6 (w/v) ratio of sweet potato to water was chosen as the most suitable condition because of the least amount of used water. The effect of settling time on the yield percent of sweet potato starch was investigated in the range of 1, 2, 3, 4 and 5 hr, respectively. It is obvious that, no appreciable increased amount of starch was obtained beyond 4hr settling time. So, 4hr settling time was selected as the most favourable condition. The results are shown in Figure (5).

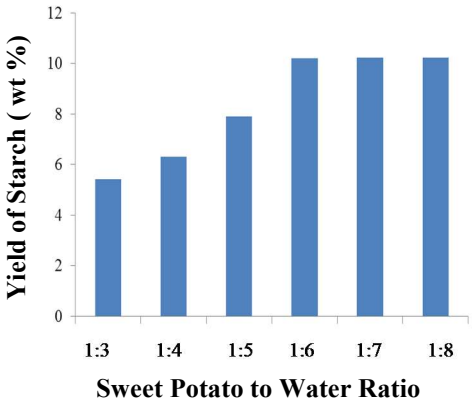

Figure 4: Effect of Sweet Potato to Water Ratio on the Yield of Sweet Potato Starch

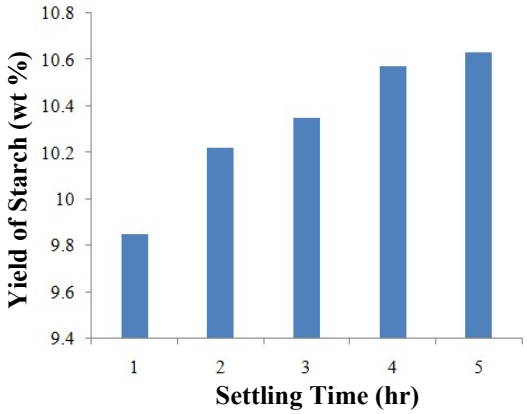

Figure 5: Effect of Settling Time on the Yield of Sweet Potato Starch

The results of Table (1) show the effect of volume of 20% hydrochloric acid on the yield of sweet potato modified starch by acid treatment. Higher volume of 20% hydrochloric acid beyond 0.5 ml gave a starch of rough texture and also the yield percent of sweet potato modified starch was decreased. When higher concentration of hydrochloric acid was used in the treatment of starch, most of the non-starchy materials were removed from the slurry. Therefore, 0.5 ml of 20% hydrochloric acid was chosen as the most suitable condition. The effect of concentration of 0.5 mL of hydrochloric acid on the yield percent of modified starch is shown in Table (2). The lower the acid concentration, the higher the yield percent of modified starch was obtained. Moreover, lower concentration of hydrochloric acid gave a smooth texture of modified starch and it was more economic. And also, it can reduce the side effect of the application of high concentration of hydrochloric acid. Therefore, 10% of 0.5 ml hydrochloric acid was selected as

the most suitable condition. Table (3) tabulates the results of the effect of reaction temperature on the yield of modified starch. 30°C reaction temperature gave the highest yield percent of modified starch (90.6%) than the others. Beyond this temperature, modified starch formed a gel due to the absorption of water.

Table 1: Effect of Volume of 20% HCl on the Yield of Modified Starch (Acid Treatment)

Weight of Starch - 5 g
Volume of 0.01(w/v)% NaOH - 1 mL
Reaction Temperature - 40°C
Reaction Time - 15 min

Sr. No.	Volume of 20% HCl (mL)	Yield (wt%)	Colour	Texture
1	0.25	84.2	odd white	smooth
2*	0.50	86.4	odd white	smooth
3	1.00	82.2	odd white	smooth
4	1.50	78.0	odd white	slightly rough
5	2.00	74.2	odd white	slightly rough
6	2.50	72.6	odd white	rough

* the most favourable condition

Table 2: Effect of Concentration of HCl on the Yield of Modified Starch (Acid Treatment)

Weight of Starch - 5g
Volume of HCl - 0.5 mL
Volume of 0.01(w/v)% NaOH - 1 mL
Reaction Temperature - 40°C
Reaction Time - 15 min

Sr. No.	Concentration of HCl (%)	Yield (wt%)	Colour	Texture
1	5	83.2	odd white	smooth
2*	10	87.6	odd white	smooth
3	20	86.4	odd white	slightly rough
4	30	84.0	odd white	slightly rough
5	40	80.2	odd white	rough
6	50	77.6	odd white	rough

* the most favourable condition

Table 3: Effect of Reaction Temperature on the Yield of Modified Starch (Acid Treatment)

Weight of Starch - 5 g
Volume of 10(v/v)% HCl - 0.5 ml
Volume of 0.01(w/v) % NaOH - 1 ml
Reaction Time - 15 min

Sr. No.	Reaction Temperature (°C)	Yield (wt%)	Colour	Texture
1*	30 (R.T)	90.6	white	smooth
2	40	87.6	white	smooth
3	50	78.8	white	smooth
4	60	77.9	white	smooth

* the most favourable condition

By varying the volume of 0.1 (w/v)% sodium tripolyphosphate such as 1, 3, 5, 7 and 9 mL, the effect of volume of 0.1 (w/v)% of sodium tripolyphosphate on the yield of sweet potato modified starch was studied. It was found that 5 mL of 0.1 (w/v)% sodium tripolyphosphate gave 92.4 (wt)% of sweet potato modified starch, which is the highest yield amongst them. The results are shown in Table (4).

Lowest concentration of sodium tripolyphosphate gave a white and smooth texture of modified starch. 0.05 (w/v) % and 0.1(w/v) % of sodium tripolyphosphate gave the 90.6% and 92.4% of sweet potato modified starch respectively. Between them, 0.1(w/v)% of sodium tripolyphosphate was selected as the most suitable condition due to its higher yield percent. The results are shown in Table (5).

The effect of reaction temperature on the yield percent of modified sweet potato starch was investigated in the range of (30, 40, 50, 60 and 70)°C, respectively. Among of them, 30°C of reaction temperature gave the highest yield percent of modified starch 93.8 wt% than the others. Beyond this temperature, modified starch absorbed water resulting in gel formation. The results are shown in Table (6).

Table 4: Effect of Volume of Sodium Tripolyphosphate on the Yield of Modified Starch (Cross-Link Method)

Weight of Starch - 5g
Volume of Water - 10 mL
Volume of 0.1(w/v %) NaOH - 5 mL
Volume of 0.3(v/v%) HCl - 3 mL
Reaction Temperature - 40ºC
Reaction Time - 60 min
Concentration of Sodium Tripolyphosphate - 0.1 % (w/v)

Sr. No.	Volume of Sodium Tripolyphosphate (mL)	Yield (wt%)	Colour	Texture
1	1	85.0	white	smooth
2	3	91.0	white	smooth
3*	5	92.4	white	smooth
4	7	92.8	odd white	slightly rough
5	9	92.2	odd white	slightly rough

* the most favourable condition

Table 5: Effect of Concentration of Sodium Tripolyphosphate on the Yield of Modified Starch (Cross-Link Method)

Weight of Starch - 5g
Volume of Water - 10 mL
Volume of 0.1(w/v%) NaOH - 5 mL
Volume of 0.3(v/v%) HCl - 3 mL
Volume of Sodium Tripolyphosphate - 5 mL
Reaction Temperature - 40ºC
Reaction Time - 60 min

Sr. No.	**Concentration of Sodium Tripolyphosphate (w/v%)**	**Yield (wt%)**	**Colour**	**Texture**
1	0.05	90.6	white	smooth
2*	0.10	92.4	white	smooth
3	0.15	90.8	odd white	slightly rough
4	0.20	90.2	odd white	slightly rough
5	0.25	89.4	odd white	slightly rough

* the most favourable condition

Table 6: Effect of Reaction Temperature on the Yield of Modified Starch (Cross-Link Method)

Weight of Starch - 5g
Volume of Water - 10 ml
Volume of 0.1(w/v%) $Na_5P_3O_{10}$ - 5 ml
Volume of 0.1(w/v%) NaOH - 5 ml
Volume of 0.3 (v/v)% HCl - 3 ml
Reaction Time - 60 min

Sr. No.	Reaction Temperature (°C)	Yield (wt%)	Colour	Texture
1*	30°C (R.T)	93.8	white	smooth
2	40°C	92.4	white	smooth
3	50°C	86.2	odd white	gel type
4	60°C	82.4	odd white	gel type
5	70°C	80.4	odd white	gel type

* the most favourable condition

Table (7) tabulates the result of characteristics of starch and modified starch such as ash, gelatinization temperature, moisture, pH, solubility, swelling power, amylose and amylopectin contents. The ash contents of starch and modified starches are similar to that of literature value. Gelatinization temperatures for starch and modified starches were found to be well comparable with the literature value. The moisture (wt%) for starch, acid treated starch and cross-linked starches were 7.08%, 6.28% and 7.16 % respectively. pH for starch, acid treated starch and cross-linked starch were found to be 6.88, 6.82 and 6.91 respectively.

Solubility and swelling power of starch, acid treated modified starch and cross- link modified starch were 24.37%, 28.12%, 32.71% and 25.45%, 33.51%, 35.87% respectively. Amylose and amylopectin contents of starch, acid treated modified starch and cross- link modified starch were 18.93%, 25.12%, 28.78% and 81.07%, 74.88%, 71.22% and respectively.

Table 7: Characteristics of Starch and Modified Starch

Characteristics	Starch		AMS		CMS	
	Experimental Value	*Literature Value	Experimental Value	*Literature Value	Experimental Value	*Literature Value
Ash (wt %)	0.13	1.64 ± 0.01	0.15	1.98 ±0.02	0.15	1.20 ± 0.05
Gel.Temp (°C)	60	62	71	70-80	75	70-80
Moisture (wt %)	7.08	8.72 ± 0.03	6.27	9.02 ± 0.07	7.16	9.08 ± 0.09
pH	6.88	6.50	6.82	6.65	6.91	6.71
Solubility(w/w%)	24.37	-	28.12	-	32.71	-
Swelling Power(w/w%)	25.45	-	33.51	-	35.87	-
Amylose Content (wt%)	18.93	-	25.12	-	28.78	-
Amylopectin Content (wt%)	81.07	-	74.88	-	71.22	-

AMS - Acid Treated Modified Starch

CMS - Cross-Link Modified Starch

* Pakistan Journal of Nutrition, 2009

The results of FT-IR spectrum of sweet potato modified starches prepared by (acid treated and cross-link methods) and commercial modified starch are demonstrated in Figures (6).The mid-infrared spectrum (4000 – 400 cm^{-1}) is approximately divided into four regions. The nature of a group frequency was determined by the region in which it is located. The regions are generalized as follows: the X – H stretching region (4000 – 2500 cm^{-1}), the triple bond region (2500 – 2000 cm^{-1}) and the fingerprint region (1500 – 600 cm^{-1}). The spectral characteristics of the prepared modified starch and commercial modified starch were found to be similar. The infrared spectra of sweet potato starch samples that originate mainly from the vibrational modes of amylose and amylopectin reflected the changes in molecular structure.

The O-H stretching region (3000-3600 cm^{-1}),C-H stretching region (2800-3000 cm^{-1}), the skeletal mode vibration of the glycosidic linkage (900-950 cm^{-1}) in infrared spectra are clearly seen for all the sweet potato modified starch. In the finger print region, there were several discernible absorbencies at 1157.73, 1080.17, 1014.59, 1157.33, 1080.17, 1018.45 and 1016.52, which were attributed to C – O bond stretching. Another characteristics peak occurred at 1641.48 cm^{-1}, which presumably originated from tightly bound

water present in the starch granules. The extremely broad band appearing most intense at 3000-3700 cm^{-1} could be attributed to the vibration of hydroxyl (O-H) groups. The band at 2931.90 and 2936.90 cm^{-1} were characteristic of C-H stretching associated with ring methane hydrogen atoms.

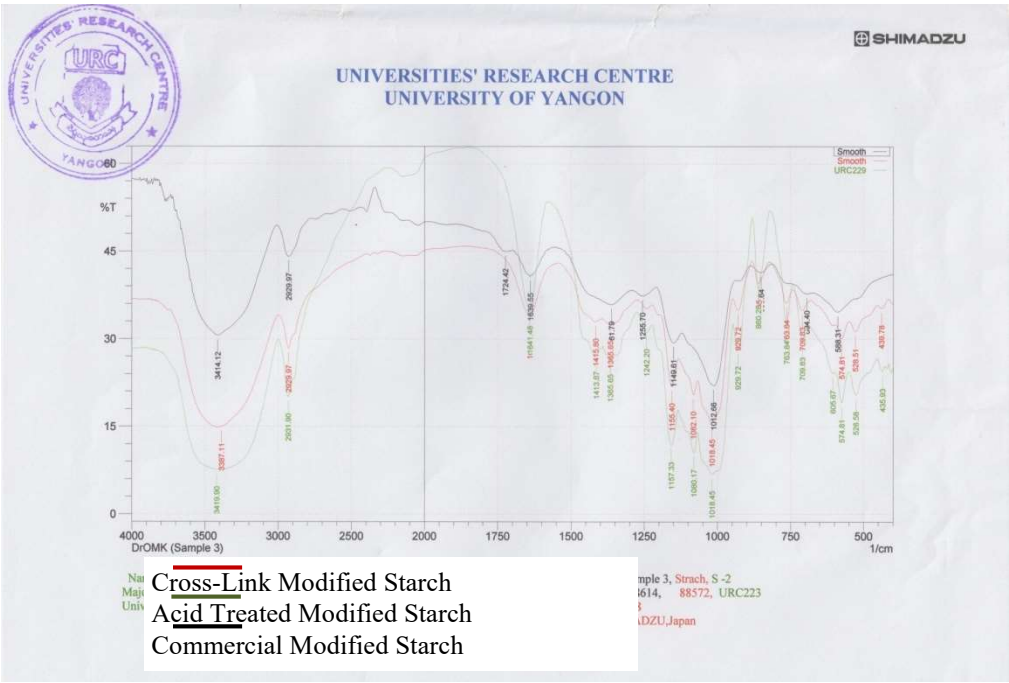

Figure 6: Comparison of FT-IR Spectrum for Acid Treated Modified Starch, Cross-Link Modified Starch and Commercial Modified Starch

Table 8: Effect of the Weight of Modified Starch on the Organoleptic Properties of Mayonnaise

Weight of Egg - 53.0 g
Weight of Sugar - 10 g
Weight of Vinegar - 20 g
Weight of Soybean Oil - 55 g
Weight of Guar Gum - 0.4 g
Room Temperature - 25-30 ºC
Weight of Common Salt - 2.0 g

Sr. No.	Weight of Modified Starch(g)	pH	Organoleptic Properties		
			Taste	Color	Texture
1	-	5.4	bad taste	pale yellow	very soft and stable emulsion
2	1.0	5.4	bad taste	pale yellow	very soft and stable emulsion
3	2.0	5.3	slightly sour taste	pale yellow	very soft and stable emulsion
4	3.0	5.3	slightly sour taste	pale yellow	very soft and stable emulsion
5	4.0	5.3	slightly sour taste	pale yellow	slightly soft and stable emulsion
6	*5.0	5.3	good taste	pale yellow	soft and stable emulsion
7	6.0	5.3	good taste	pale yellow	thick and slightly sticky
8	7.0	5.3	good taste	pale yellow	very thick and sticky

*the most favourable condition

Table 9: Formulae for the Preparation of Butter Biscuit

Formulae	Ingredient (wt %)			Organoleptic Properties			
	Starch	M.S	F	Colour	Texture	Taste	Odour
I	-	-	30	pale yellow	very rough	good taste	pleasant smell
II	30	-	-	pale yellow	bland	good taste	pleasant smell
III	-	30	-	pale yellow	very soft	good taste	pleasant smell
IV	10	-	20	pale yellow	very rough	good taste	pleasant smell
*V	-	20	10	pale yellow	smooth	good taste	pleasant smell
VI	-	15	15	pale yellow	slightly rough	good taste	pleasant smell
VII	-	10	20	pale yellow	very rough	good taste	pleasant smell

M.S - Modified Starch
F - Wheat Flour
*the most favorable condition

Mayonnaise

Biscuit

Conclusion

Starch was firstly produced from sweet potato and then it was modified using both acid treatment method and cross-link methods. According to the results of the characteristics and yield % of modified starch using two different modified starch. When equal amount of modified and flour were used in formulation of biscuit, it gave a slightly rough texture biscuit. The ratio of modified starch to flour 2:1 gave a smooth texture biscuit. In conclusion, if 20% of modified starch was used in the preparation of biscuit, the texture of biscuit was smooth and good. The prepared mayonnaise using

only the modified starch instead of the mixture of guar gum and modified starch gave a good texture, smooth and stable emulsion. It can be controlled by the syneresis and increase the viscosity, mouthfeel and stability of mayonnaise.

Acknowledgement

We would like to express our sincere gratitude to Dr Aye Aye Tun, Pro-rector, Dagon University for her permission and the financial support in this research work. We are grateful to Dr Yin Shwe, Professor and Head (Retd), Department of Industrial Chemistry, Dagon University for her kind encouragement and numerous invaluable suggestions.

References

Abbas K.A., et al., (2010). Modified Starches and Their Usages in Selected Food Products: A Review Study, Journal of Agricultural Science, Vol. 2, No. 2.

Bo Bo., Sandi.(2016,).Preparation of Modified Starch from Sweet Potato and its Application in Food Processing

Hoover, R. and Sosulski, F.W. (1985).Studies on the Functional Characteristics and Digestibility of Starches from Phaselous Vulgaris Biotypes.

Kavlani N, et al., (2012).Various Techniques for the Modification of Starch and the Applications of its Derivatives, International Research Journal of Pharmacy.

Ko., Phyu Hnin. (2017)Utilization of Sweet Potato Modified Starch for Some Food Products

Moorthy, S. N. (2002). Physico-chemical and Functional Properties of Tropical Tuber Starches.

Mohan, J., (2000), Organic Spectroscopy Principle and Applications, Narosa Publishing New Delhi.