



UNIVERSITI PUTRA MALAYSIA

**PREPARATION AND CHARACTERISATION OF CROSS-LINKED
SAGO STARCH PHOSPHATES**

FARIDAH BINTI HUSSIN

FSMB 1998 18

**PREPARATION AND CHARACTERISATION OF CROSS-LINKED
SAGO STARCH PHOSPHATES**

FARIDAH BINTI HUSSIN

**MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA**

1998



**PREPARATION AND CHARACTERISATION OF CROSS-LINKED
SAGO STARCH PHOSPHATES**

By

FARIDAH BINTI HUSSIN

**Thesis Submitted in Fulfillment of the Requirements for the Degree of
Master of Science in the Faculty of Food Science and Biotechnology
Universiti Putra Malaysia**

September 1998



ACKNOWLEDGEMENTS

Alhamdulillah, first of all I would like to express my utmost thanks and gratitude to Almighty Allah S.W.T. who has given me the capability to complete this project and my salawat and salam to His messenger, Prophet Muhammad s.a.w.

I would like to express my most sincere appreciation and deepest gratitude to my supervisor, Dr. Sharifah Kharidah binti Syed Muhammad for her understanding, willingness, generous gift of time and guidance, invaluable advice, constructive suggestions and valuable comments which had helped tremendously in the preparation of this thesis. I am also very grateful for the patience, care and encouragement that she had so generously offered during this study and in reviewing the manuscript.

My heartfelt appreciation and sincere thanks goes to the member of my supervisory committees, Prof. Dr. Yaakob bin Che Man and Prof. Madya Dr. Hasanah binti Mohd Ghazali who had selflessly devoted their time to read and review the manuscript in great detail time after time. Their generous guidance, invaluable comments, advice and suggestions in the preparation of this thesis is deeply appreciated. I would also like to express my sincere thanks for their care and encouragement during the course of my study in UPM and most of all for their warm friendship.

My appreciation and special thanks also goes to my former supervisor, Dr. Mohd. Nasir bin Azudin for his brilliant ideas, technical guidance and advice during this study.



My deepest appreciation and gratitude are accorded specially to En. Dzulki-fly Mat Hashim, En. Razali Mustaffa, Pn. Zaulia Othman, En. Amin Ismail, Miss Irene Ch'ng, Dr. Puziah Hashim, Cik Jamaliah Ahmad, En. Azman Abu Yamin, En. Chan Tin Wan, Kak Hus, En. Halim, Dr. Mwanjallah Mwasaru, Miss Malini and all my friends, technicians, laboratory assistants and staff members of the Faculty of Food Science and Biotechnology for their very generous help, care, encouragement and warm friendship which had made my study in UPM a very pleasant and memorable experience.

Most of all, I would like to express my deepest gratitude to my beloved parents, husband, and children for their endless encouragement, love, patience and sacrifices which helped me in my undertakings and to complete this work.



TABLE OF CONTENTS

	Page
AKNOWLEDGEMENTS	ii
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF PLATES	xii
LIST OF ABBREVIATIONS	xiii
ABSTRACT	xiv
ABSTRAK	xvi
CHAPTER	
1 GENERAL INTRODUCTION	1
2 LITERATURE REVIEW	5
Modified Starches	5
Cross-linked Starch	8
Manufacturing Process	8
Effect of Processing Parameters	12
General Reactions	15
Types of Starches	20
Characteristics and Properties of Cross-linked Starch.....	20
Phosphorus in Starch	20
Pasting Profile	21
Degree of Substitution (DS).....	26
Sediment Volume	27
Paste Clarity	28
Water Holding Capacity	29
Swelling Power and Solubility	31
Scanning Electron Microscopy	32
Gel Strength of Starch Paste	32
Freeze-thaw Stability	33
Starch Damage	36
Utilisation	36
Sago starch	39
Origin	39
Extraction of Sago Starch.....	40
Properties and Chemical Compositions	40
Utilisation	41



3 EFFECT OF VARIOUS PROCESSING PARAMETERS ON THE PHOSPHORUS CONTENT, PASTING PROFILE, AND PASTE CLARITY OF PHOSPHORYLATED SAGO STARCH

Introduction	44
Materials and Methods	45
Materials	45
Starch Damage	46
Total Amylose	48
Phosphorylation of Starch	49
Phosphorus Content	50
Pasting Profiles	50
Paste Clarity	51
Results and Discussion	51
Effect of pH on the Sago Starches Phosphorylated with STMP, STPP, and Mixture of the Two	53
Effect of Sodium Tripolyphosphate (STPP) Concentrations	63
Effect of Sodium Trimetaphosphate (STMP) Concentrations	69
Effect of Sodium Sulfate Concentrations	74
Effect of Reaction Time	78
Effect of Reaction Temperature	83
Effect of Heating Time	89
Effect of Heating Temperature	92
Conclusions	98

4 PHYSICO-CHEMICAL CHARACTERISTICS OF CROSS-LINKED SAGO STARCH COMPARED WITH COMMERCIAL CROSS-LINKED WAXY CORN STARCHES

Introduction	99
Materials and Methods	100
Materials	100
Preparation of Cross-linked Sago Starch	101
Phosphorus Content of Starch	101
Degree of Substitution	101
Swelling Power and Solubility	102
Pasting Profile	102
Paste Clarity	102
Sediment Volume	103
Gel Strength of Starch Paste	103
Acid and Heat Stability	104
Water Holding Capacity	104
Freeze Thaw Stability of Gels	105
Scanning Electron Microscopy (SEM)	105
Starch Damage	106



Results and Discussion	106
Phosphorus Content of Starch	106
Degree of Substitution	108
Swelling Power and Solubility	108
Pasting Profiles.....	111
Paste Clarity	113
Sediment Volume	115
Gel Strength of Starch Paste	117
Acid and Heat Stability	119
Water Holding Capacity	124
Freeze-Thaw Stability of Gels	126
Scanning Electron Microscopy (SEM)	128
Starch Damage	133
Conclusion	133
5 GENERAL CONCLUSION AND RECOMMENDATIONS ..	136
General Conclusion and Recommendations.....	136
BIBLIOGRAPHY	139
BIOGRAPHICAL SKETCH.....	153



LIST OF TABLES

Table		Page
1	Disadvantages of unmodified starches	6
2	Types of modified starches	7
3	Dissociation constant of phosphoric acids	16
4	Effect of autoclaving on brookfield viscosity and solubility of starches	26
5	Water binding capacities of native and modified starches	30
6	Influence of cross-linking on granular swelling power (GSP) of corn and waxy corn	32
7	Properties of starches	42
8	Physico-chemical composition of sago starch	52
9	Phosphorus content of native, cross-linked sago and cross-linked waxy corn starches (Mazaca 3543X and Mazaca 3544X) .	107
10	Degree of substitution of native, cross-linked sago and cross-linked waxy corn starches (Mazaca 3543X and Mazaca 3544X) .	109
11	Water holding capacity of native, cross-linked sago and cross-linked waxy corn starches (Mazaca 3543X and Mazaca 3544X) .	125
12	Starch damage of native sago, cross-linked sago and cross-linked waxy corn starches (Mazaca 3543X and Mazaca 3544X) .	134

LIST OF FIGURES

Figure		Page
1	Cross-linking to supplement hydrogen bonding in a starch granule	9
2	Structure of distarch Glycerol (A) and distarch phosphate	9
3	Reactions of sodium tripolyphosphate with starch at alkaline and acidic pH. Slanted arrow indicates the phosphate attacked by a starch hydroxyl	17
4	Reactions of sodium trimetaphosphate with starch at alkaline and acidic pH. Slanted arrow indicates the phosphate attacked by a starch hydroxyl	18
5	Effect of cross-linking corn starch on brabender viscograph	24
6	Effect of cross-linking waxy corn starch on brabender viscograph at pH 5 and 3	23
7	Meaning of DS and MS. On the left, the molecules has only one substituent X, which gives a DS and MS equal to 1. On the right, there are three substituents X, which gives a DS of 1 and a MS of 3.	27
8	Freeze-thaw stability of 5% pastes of various starches	35
9	Effect of various initial reaction pH on the total phosphorus content of sago starch phosphates prepared using 2% sodium trimetaphosphate (STMP), 5% sodium tripolyphosphate (STPP), and a mixture of the two	54
10	Amylograms of sago starch phosphates prepared by reacting starch at various initial pH levels with 5% sodium tripolyphosphate based on dry starch. All amylograms were obtained at pH 6.5 and 6% starch solids	57
11	Amylograms of sago starch phosphates prepared by reacting starch at various initial pH levels with 2% sodium trimetaphosphate based on dry starch. All amylograms were obtained at pH 6.5 and 6% starch solids	58
12	Amylograms of sago starch phosphates prepared by reacting starch at various initial pH levels with a mixture of 5% sodium sulfate, 5% sodium tripolyphosphate and 2% sodium trimetaphosphate based on dry starch. All amylograms were obtained at pH 6.5 and 6% starch solids	60

13	Paste clarity of sago starch phosphates prepared using 5% sodium tripolyphosphate (STPP), 2% sodium trimetaphosphate (STMP), and a Mixture of the two at various pH levels	62
14	Effect of sodium tripolyphosphate concentrations on the total phosphorus content of sago starch phosphates prepared at pH 11...	64
15	Amylograms of sago starch and sago starch phosphates prepared at various concentrations of sodium tripolyphosphate (STPP) based on dry starch at pH 11. All amylograms were obtained at pH 6.5 and 6% starch solids	66
16	Effect of sodium tripolyphosphate concentrations on paste clarity of sago starch phosphates prepared at pH 11 based on dry starch...	68
17	Effect of sodium trimetaphosphate concentrations on the total phosphorus content of sago starch phosphates prepared at pH 8...	70
18	Amylograms of sago starch and sago starch phosphates prepared at various concentrations of sodium trimetaphosphate (STMP) based on dry starch at pH 8. All amylograms were obtained at pH 6.5 and 6% starch solids	71
19	Effect of sodium trimetaphosphate concentrations on paste clarity of sago starch phosphates prepared at pH 8 based on dry starch	73
20	Effect of sodium sulfate concentrations on the total phosphorus content of sago starch phosphates prepared using a Mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	75
21	Amylograms of sago starch and sago starch phosphates prepared by reacting starch at various concentrations of sodium sulfate based on dry starch at pH 9.5. All amylograms were obtained at pH 6.5 and 6% starch solids	77
22	Effect of sodium sulfate concentrations on paste clarity of sago starch phosphates prepared using 5% sodium tripolyphosphate (STPP) and 2% sodium trimetaphosphate (STMP) at based on dry starch pH 9.5.....	79
23	Effect of various reaction times on the total phosphorus content of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	80
24	Amylograms of sago starch and sago starch phosphates prepared by reacting starch at various reaction times at pH 9.5. All amylograms were obtained at pH 6.5 and 6% starch solids	82

25	Effect of various reaction times on paste clarity of sago starch phosphates prepared using 5% sodium tripolyphosphate (STPP) and 2% sodium trimetaphosphate (STMP) at based on dry starch pH 9.5.....	84
26	Effect of various reaction temperatures on the total phosphorus content of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	85
27	Amylograms of sago starch and sago starch phosphates prepared by reacting starch at various reaction temperatures at pH 9.5. All amylograms were obtained at pH 6.5 and 6% starch solids	87
28	Effect of various reaction temperatures on paste clarity of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	88
29	Effect of various heating times on the total phosphorus content of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	90
30	Amylograms of sago starch and sago starch phosphates prepared by reacting starch at various heating times at pH 9.5. All amylograms were obtained at pH 6.5 and 6% starch solids	91
31	Effect of various heating times on paste clarity of sago starch phosphates prepared using 5% sodium tripolyphosphate (STPP) and 2% sodium trimetaphosphate (STMP) at based on dry starch pH 9.5.....	93
32	Effect of various heating temperatures on the total phosphorus content of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	94
33	Amylograms of sago starch and sago starch phosphates prepared by reacting starch at various heating temperatures at pH 9.5. All amylograms were obtained at pH 6.5 and 6% starch solids	96
34	Effect of various heating temperatures on paste clarity of sago starch phosphates prepared using a mixture of 2% sodium trimetaphosphate and 5% sodium tripolyphosphate based on dry starch at pH 9.5	97
35	Swelling power and solubility of native sago, sago and waxy corn starches	110

36	Amylograms of native sago, cross-linked waxy corn (Mazaca 3543X and Mazaca 3544X) starches.	112
37	Paste clarity of native sago, starches	114
38	Sediment volume of native sago, corn starches	116
39	Gel strength of native sago, starches	118
40	Acid and heat stability of native sago starch. All amylograms were obtained at 6% starch solids	120
41	Acid and heat stability of cross-linked sago starch. amylograms were obtained at 6% starch solids	121
42	Acid and heat stability of cross-linked waxy corn starch (Mazaca 3543X). All amylograms were obtained at 6% starch solids	122
43	Acid and heat stability of cross-linked waxy corn starch (Mazaca 3544X). All amylograms were obtained at 6% starch solids	123
44	Freeze-thaw stability of native sago, cross-linked sago and waxy corn starches (Mazaca 3543X and Mazaca 3544X). One cycle is equal to two days of storage	127

LIST OF PLATES

Plate		Page
1	Scanning electron micrographs of native sago starch at 500X and 1,000X magnifications	129
2	Scanning electron micrographs of cross-linked sago starch at 450X and 1800X magnifications	130
3	Scanning electron micrographs of cross-linked waxy corn starch (Mazaca 3543X) at 550X and 2000X magnifications.....	131
4	Scanning electron micrographs of cross-linked waxy corn starch (Mazaca 3544X) at 850X and 2000X magnifications.....	132

LIST OF ABBREVIATIONS

AGU	Anhydroglucose unit
BU	Brabender unit
°C	degree Centigrade
DS	Degree of Substitution
dsb	dry starch basis
gm	gram
hr	hour
M	Molar
min	minute (s)
ml	milliliter
nm	nanometer
P	Phosphorus
CFR	Code of Federal Regulation
SIRIM	Standard and Industrial Research Institute of Malaysia
STMP	Sodium trimetaphosphate
STPP	Sodium tripolyphosphate
UV	Ultra Violet
VIS	Visible
µm	micrometer
<	less than
%	percent



Abstract of Thesis Presented to the Senate of Universiti Putra Malaysia in
Fulfillment of the Requirements for the Degree of Master of Science.

PREPARATION AND CHARACTERISATION OF CROSS-LINKED SAGO STARCH PHOSPHATES

BY

FARIDAH HUSSIN

September, 1998

Supervisor : Sharifah Kharidah Bte Syed Muhammad, Ph. D.

Faculty : Food Science and Biotechnology

This project was conducted to study the production of cross-linked sago starch phosphate and to characterise the material produced. Sago starch was phosphorylated at various pHs (from 6 to 11) under a range of phosphate salt concentrations (sodium tripolyphosphate [STPP] [1 to 9%] and sodium trimetaphosphate [STMP] [1 to 4%]) and in the presence of various sodium sulfate concentrations (1 to 9%). The phosphorylation was carried out for 40 to 80 mins at temperatures varying from 27 to 50°C and heating time from 0.5 to 3 hrs at temperatures between 100 to 160°C. It was observed that the reaction pH and concentration of phosphate salts played a significant effect on the phosphorus (P) content, pasting profile, and paste clarity of the sago starch phosphates produced. The phosphorus content was found to increase as the pH and concentration of phosphate salts were increased under all conditions. However, the phosphorus contents were found to be below the standard (STPP [0.4%], STMP [0.04%], and a mixture of STPP and STMP [0.4%]), except when the concentration of STMP was above 1%. The pasting profile showed that at pH 9.5, treatment of sago starch with a



mixture of 5% STPP and 2% STMP yielded the best cross-linked sago starch phosphate where it showed the lowest hot paste viscosity and the highest cold paste viscosity. Paste clarity measurements of the phosphorylated starches indicated that cross-linking had accelerated rapidly with STMP above pH 8, with STPP above pH 9, and with a mixture of the two above pH 6. Paste clarity measurements also showed that cross-linking began to accelerate at 5% and below STPP, and 2% and below STMP when sago starch was phosphorylated at pH 11 and 8, respectively. Judging from the paste properties, phosphorylation of sago starch at 27°C for 1 hr with a mixture of 5% STPP and 2% STMP at pH 9.5 in the presence of 5% sodium sulfate and then heating at 130°C for 2 hr is recommended. Cross-linked sago starch phosphate and commercial cross-linked waxy corn starch (Mazaca 3543X and 3544X) showed similar pasting profile. However, cross-linked sago starch phosphate had higher degree of phosphorylation (phosphorus content), degree of substitution, swelling power and solubility, paste clarity and gel strength. The water holding capacity and sediment volumes were similar to one of the cross-linked waxy corn starches (Mazaca 3544X). Morphology studies showed that these modified starches retained their granule shape with minimal degree of starch damage.

Abstrak tesis yang dikemukakan Kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi Syarat Keperluan Untuk Ijazah Sarjana Sains

PENYEDIAAN DAN PENCIRIAN KANJI SAGU IKATAN-SILANG FOSFAT

Oleh

FARIDAH HUSSIN

September, 1998

Penyelia : Sharifah Kharidah Bte Syed Muhammad, Ph. D.

Fakulti : Sains Makanan dan Bioteknologi

Projek ini dijalankan untuk mengkaji penghasilan dan pencirian kanji sagu fosfat ikatan-silang daripada kanji sagu. Kanji sagu telah difosforilasi pada pH yang berbeza (dari 6 ke 11) dengan menggunakan kepekatan garam-garam fosfat yang berbeza (sodium tripolifosfat [STPP] [1 hingga 9%] dan sodium trimetafosfat [STMP] [1 hingga 4%]) dan dengan kehadiran kepekatan sodium sulfat yang berbeza (1 hingga 9%). Fosforilasi telah dijalankan selama 40 hingga 80 minit pada suhu daripada 27 hingga 50°C dan dipanaskan selama 0.5 hingga 3 jam pada suhu diantara 100 hingga 160°C. Didapati paras pH tindakbalas dan kepekatan garam-garam fosfat menunjukkan kesan yang bermakna keatas kandungan fosforus (P), profil kelikatan, dan kejernihan pes kanji-kanji sagu fosfat yang dihasilkan. Kandungan fosforus didapati bertambah apabila pH dan kepekatan garam-garam fosfat bertambah pada semua keadaan. Walaubagaimanapun, kandungan fosforus didapati di bawah paras piawaian (STPP [0.4%], STMP [0.04%], dan campuran STPP dan STMP [0.4%]), kecuali apabila kepekatan STMP melebihi 1%. Profil kelikatan menunjukkan bahawa kanji sagu yang dirawat dengan campuran 5% STPP dan 2% STMP pada pH 9.5 menghasilkan kanji fosfat yang terbaik dimana ia



menunjukkan kelikatan pes panas yang terendah dan kelikatan pes sejuk yang lebih tertinggi. Pengujian kejernihan pes ke atas kanji yang telah difosforilasi menunjukkan bahawa ikatan-silang telah meningkat dengan cepatnya pada pH lebih daripada 8 dengan STMP, lebih daripada 9 dengan STPP, dan lebih daripada 6 dengan campuran kedua-duanya. Pengukuran kejernihan pes juga menunjukkan bahawa ikatan-silang mula bertambah pada 5% STPP dan ke bawah, dan ke bawah apabila kanji sagu difosforilasikan pada pH 11 dan 8, masing-masing. Merujuk kepada ciri-ciri kelikatan, difosforilasi pada suhu 27°C selama 1 jam dengan menggunakan campuran 5% STPP dan 2% STMP pada pH 9.5 dengan kehadiran 5% sodium sulfat dan kemudiannya dipanaskan pada suhu 130°C selama 2 jam digunakan. Kanji sagu fosfat ikatan-silang dan kanji jagung berlilin ikatan silang (Mazaca 3543X dan 3544X) menunjukkan profil kelikatan yang sama. Walaubagaimanapun, ikatan silang menunjukkan darjah fosforilasi (kandungan fosforus), penggantian, kuasa pengembangan dan kelarutan, kejernihan pes dan kekuatan gel yang lebih tinggi. Kapasiti pegangan air dan isipadu mendapan adalah sama dengan salah satu daripada kanji-kanji jagung berlilin ikatan silang (Mazaca 3544X). Kajian morfologi menunjukkan kanji-kanji yang telah diubahsuai ini tidak berubah bentuk granul asalnya dengan darjah kerosakan yang rendah.

CHAPTER 1

GENERAL INTRODUCTION

Cross-linked starches are those products resulting from an intentional reaction of starch with bi- or polyfunctional reagents, which will effect a bond between glucose units on separate chains. They are widely used as thickening agents in sauces and dressing, bakery products, puddings, desserts and custards, soups, and emulsifying agent in many food systems, antiblocking dusting agent, warp sizing of denims and surgical dusting powder in other applications (Swinkels, 1992). The types of cross-linked that are of commercial value are distarch adipates, distarch phosphates, and distarch glycerol. Of these, only distarch phosphates and distarch glycerol are used in making modified food starches (Wurzburg, 1986b). In this study, distarch phosphates will be produced through phosphorylation because it is a method commonly employed for cross-linking starches intended for the food industry and other uses (Koch *et al.*, 1982).

Distarch phosphates are produced when a phosphate radical bridges two starch molecules and in consequence the starch granule is inhibited from swelling and rupture on pasting in water (Radley, 1976). A small amount of cross-linking greatly reduces both the rate and the degree of granule swelling and sensitivity of starch pastes to processing conditions.



Starch can be cross-linked by reaction with various inorganic phosphate salts as well as specially developed organic reagents. The U.S. Food and Drug Administration allows starch for use in foods to be modified with sodium trimetaphosphate (residual phosphorus not exceeding 0.04%), sodium trimetaphosphate and sodium tripolyphosphate (residual phosphorus not exceeding 0.4%) and phosphorus oxychloride (maximum allowable treatment is 0.1% on starch) (CFR, 1991).

Cross-linked starches have been produced mainly in United States, Europe, Japan and Australia. These products are mostly derived from corn and tapioca starch. As a result, technical information regarding the manufacturing process and the various processing parameters are based on modifications of these starches (Wurzburg, 1986; Rutenberg and Solarek, 1984; Kerr and Cleveland, 1959)

In Malaysia, modified starches are imported for utilization in the local food industries and other applications. Referring to the statistics on import and re-export of merchandises prepared by the Malaysian Industrial Development Authority (MIDA), from January 1995 to August 1996, this country has imported 31,286,116.63 tonnes of modified starches which is equivalent to RM64,911,550.00. United States, Italy, Thailand, Australia, France and Germany supply these modified starches. To date, there is only one local factory producing commercial cross-linked starch either for local utilization or for export. This factory is producing cross-linked starch using waxy corn starch which is imported from Australia. Therefore, if cross-linked starch can be manufactured using one of the local indigenous starches, this



will not only save revenue but also diversify the usage of such starch. One such possible indigenous starch which Malaysia is the largest producer and exporter of is sago starch (Azudin and Lim, 1991).

Sago palm occurs throughout Malaysia and it is substantially common in fresh water swamp areas along some river courses and on peat soils (Othman, 1991). Sago starch which is extracted from sago palm has been produced primarily in Sarawak. The main areas of sago starch production in Sarawak are Mukah, Dalat and Igan of the Sibu division. During the last decade, Sarawak has been exporting about 25,000 - 30,000 tonnes of sago starch annually to Peninsular Malaysia, Singapore, Japan and other parts of the world. This monopoly is basically due to the well established sago cultivation areas available and the large scale production of sago starch practiced in this state (Zulpilip *et al.*, 1991). In addition, over the past five years there has been a tremendous improvement in starch extraction and processing technology producing high quality sago starch. Azudin *et al.* (1989) in their evaluation of the local starch have shown that sago starch produced by the modern sago factories are well above the quality specifications of the Standard and Industrial Research Institute of Malaysia (SIRIM) standards for sago starch.

Sago starch has been utilized mainly in the production of 'bee hoon' (or vermicelli), manufacture of monosodium glutamate, glucose, maltose, dextrose, and fish and prawn crackers (Zulpilip *et al.*, 1991). There has been no report or literature on the suitability of sago starch for the production of modified starch especially cross-linked starch. Therefore, the objectives of this study were:

1. To establish the optimum conditions for phosphorylating sago starch
2. To determine the physico-chemical characteristics of the cross-linked sago starch, and to compare them with that of commercial cross-linked waxy corn starches

CHAPTER 2

LITERATURE REVIEW

Modified Starches

Modified starch is a native starch treated in such a way as to modify one or more of its original physical or chemical properties (Swinkels, 1992). Modification is carried out because unmodified starches cannot be tailored-made and very often are not the best product in a particular application or process as swell with ease and rupture with minimum abuse to produce weak-bodied, cohesive pastes or undesirable gels (Wurzburg, 1986a). The main disadvantages of unmodified starches are shown in Table I.

Modifications of native starches are carried out in order to overcome these disadvantages and thus expand the usefulness of starch for a great number of industrial applications (Wurzburg, 1986a). They are designed to change and improve one or more of the properties as appropriate for a specific application (IFI, 1993) (Table 2).



Table 1: Disadvantages of unmodified

1. **Inconsistent viscosity.** Due to the effects of climatic condition of the plant.
2. **Susceptibility to acid attack.** Many food are acidic food product made using an unmodified starch will unmodified starch is degraded by the acid hydrolysis
3. **Susceptibility to shear.** An unmodified starch will viscosity due to the mechanical action of stirring. The the viscosity of the final product depending upon how been stirred.
4. **Set-back and syneresis.** In solution the hydrogen increases with time as thermal motion brings various close enough proximity for further hydrogen bonding as a colloidal sol 'sets back' into a gel on standing. the process continues with occluded water molecules gel to leave a rubbery solid surrounded by the expressed accelerated if the product is frozen then thawed.
5. **Solubility.** A problem arises in any process requiring content due to the limit on the amount that can be 'dis' as a colloid, imposed by the macromolecular nature of

Source : Rothwell and Garner (1986)

